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Henk Plessius
HU University of Applied Sciences, Utrecht, the Netherlands, henk.plessius@hu.nl

Pascal Ravesteyn
HU University of Applied Sciences, Utrecht, the Netherlands, pascal.ravesteijn@hu.nl

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Henk Plessius
HU University of Applied Sciences, Utrecht, the Netherlands
henk.plessius@hu.nl

Pascal Ravesteyn
HU University of Applied Sciences, Utrecht, the Netherlands
pascal.ravesteijn@hu.nl

Abstract

In the field of IT, many competence frameworks exist. An important framework is the European e-Competence Framework (e-CF) that quite recently has been appointed as a standard by the European Committee for Standardization CEN. In this paper we define quality characteristics for competence frameworks and show how the e-CF has been mapped on descriptions of the IT domain. Our conclusion is that the e-CF does comply almost fully with the formulated quality standards. According to our mappings, the e-CF covers the IT domain, albeit on some topics better than on others. To overcome the deficiencies identified, we advise to add to the e-CF a more explicit mentioning of attitude aspects and of the contexts in which the various competences are to be employed.

Keywords: IT competence framework, IT domain, Mapping of competence frameworks, European e-competence framework

1 Introduction

The famous expression πάντα χωρεῖ καὶ οὐδὲν μένει (Everything changes and nothing stands still) - attributed to the Greek philosopher Heraclitos [1] - seems very apt to describe the field of Information Technology (IT) where new areas of expertise arise almost every year and old areas are getting less important or even disappear totally (Benamati & Lederer, 2001). The implication is that for a career in IT, it is of paramount importance to keep up-to-date with current technology and its usage in business and society (Rong & Grover, 2009). Stated differently: IT-professionals must develop their IT-competences continually to be able to cope with the challenges of modern IT.

To express one's competences in the field of IT, various competence frameworks have been developed. Some widespread examples are the Information Technology Competency Model (ITCM, 2012), the European e-Competence Framework (e-CF,

[1]) As quoted by Plato in his dialogue Cratylos.

2014) and the Skills Framework for the Information Age (SFIA, 2015), but many more frameworks (with a national or international scope) exist. Ferrari (2012) for example gives an overview of 15 frameworks used in Great Britain alone. In our opinion, this multitude of frameworks justifies the need for a meta-framework of IT competences on which other frameworks can be mapped.

In the long run this study is concerned with the establishment of such a meta-framework, either by using one of the existing frameworks or by constructing a new one. In this research we have chosen the e-CF as a foundation because it is the first sector-specific implementation of the European Qualifications Framework (EQF). Furthermore, as of January 2016 the e-CF is approved as standard by the European Committee for Standardization (CEN, 2016), which means that it has to be implemented by all EU member states. The e-CF, as expressed by CEN (CEN, 2016) "provides a common language for competences, skills and proficiency levels that can be understood across Europe". For these reasons we have started our research with determining if the e-CF can function as a meta-framework for IT competences.

A necessary (but not sufficient) condition for the e-CF to be able to function as a meta-framework is that the domain of IT should be covered wholly by the e-CF. This paper reports the results of our research on this topic where the research question underlying our work is: *To what extent does the e-CF cover the domain of IT?*

The paper is structured as follows: in the next section we discuss the theoretical background of our research question and discuss definitions of the main concepts like competence, competence framework and IT-domain as well as the quality aspects of mappings. This discussion is followed in section 3 with an outline of our research method and an overview of the mapping itself in section 4. In section 5, we discuss our findings and compare our results with those of other authors and give suggestions for further research.

2 Theoretical Background

2.1 Competence

'Competence' is an abstract concept, created to represent something that is not directly apparent in the world. This is, according to Lundqvist, Baker & Williams (2011), the reason that no uniform definition exists of the term. In most definitions, a competence consists of "a combination of knowledge, skills and attitude that results in successful behavior in a specific context" (Dochy & Nickmans, 2005). Based on this definition it can be deducted that to describe a competence, at least four elements are necessary: the *knowledge* base that can be called upon, the *skills* and the *attitude* characteristics necessary to perform and the *context* in which to perform.

However, in practice many specifications of competences focus on the knowledge and skills part and do not explicitly state the attitude part and/or the context. For example, in the e-CF a competence is defined as: "Competence is a demonstrated ability to apply knowledge, skills and attitudes for achieving observable results" (e-CF, 2014) and no mention is made of the context.

An attempt at handling the issues of behavioral and context specific aspects of competences can be found in an earlier research by Ravesteyn, Bosman & Mens (2015). Another route is chosen in the ITCM framework where attitude and context are represented as different competences that can be combined with IT knowledge and skills (ITCM, 2012). In this approach professional competences, personal effectiveness and contextual skills are separate classes of competences.

2.2 Competence Frameworks

A coherent set of competences is called a competence framework. A competence framework offers "generic and theoretical solutions for comparing and harmonizing competencies" (Lundqvist, Baker & Williams, 2011). A competence framework usually has a scope, e.g. to make the distinction between functions in an organization, to develop courses, etcetera. In some frameworks this scope is quite broad: The European/International Computer Driving License (ECDL/ICDL, 2007) for example is targeted at raising computer literacy for every citizen. Other frameworks are more specific, e.g. the e-CF (2014) provides "a tool to support mutual understanding and provide transparency of language through the articulation of competences required and deployed by ICT professionals (including both practitioners and managers)".

A competence framework is essentially a classification of competences (Markowitsch, & Plaimauer, 2009) along one or more axes or dimensions. Competences in a competence framework are at least ordered along a domain axis: a (structured or unstructured) list of competences, where each competence-class may be subdivided further (Markowitsch, & Plaimauer, 2009). Quite often we see a second axis with proficiency levels. The e-CF for example uses five proficiency levels ranging from associate to principal (e-CF, 2014). Examples of other classification dimensions are knowledge and skills versus attitude and context (ITCM, 2012) and threshold versus performance competences (Eschenbrenner & Nah, 2014).

Following the observations above we call a classification scheme like a competence framework *simple* when it exists of a set of (competence-)classes only. If there exist relations between the classes as well (often expressed in other dimensions) we call the scheme *complex*.

For a competence framework to be a meaningful and broadly applicable standard, it should at least comply with two general classification requirements (Cobbold et al., 2002):

- *Completeness*, i.e. every competence in the domain targeted by the framework can be mapped on the framework.
- *Unambiguous*, i.e. a competence in the domain targeted by the framework can be mapped on the framework in only one way.

For a complex framework a third requirement is necessary:

- *Orthogonality*, i.e. every dimension of the framework has a meaning independent of the other dimensions.

Together these requirements guarantee that every combination of dimensions in the framework has one and only one meaning.

2.3 The e-CF

As stated in the Introduction, we have chosen to use the e-CF as the competence framework underlying our research because of its increasing importance in the European Union. The e-CF can be considered as a complex framework with two axes: the competence-classification axis and the proficiency-level axis.

In the description of the structure of e-CF (e-CF, 2014) four so-called dimensions are distinguished (note that the word dimension has a slightly different meaning in the e-CF then in our use of the term in the previous paragraph):

"These dimensions reflect different levels of business and human resource planning requirements in addition to job/work proficiency guidelines and are specified as follows:

- *Dimension 1*: Five e-Competence areas, derived from the ICT business processes PLAN – BUILD – RUN – ENABLE – MANAGE
- *Dimension 2*: A set of reference e-Competences for each area, with a generic description for each competence. Currently 40 competences are identified that together provide the European generic reference definitions of the e-CF 3.0.
- *Dimension 3*: Proficiency levels of each e-Competence provide European reference level specifications on e-Competence levels e-1 to e-5, which are related to the EQF levels 3 to 8.
- *Dimension 4*: Samples of knowledge and skills relate to e-Competences in dimension 2. They are provided to add value and context and are not intended to be exhaustive." (e-CF, 2014)

e-CF dimension 2 and 3 define the two axes of the framework, where dimension 1 is an overall classification to relate the framework to the business process of IT. Dimension 4 describes in more detail the knowledge and skills elements constituting the various competences. The attitude aspect is kept quite implicit in all dimensions.

2.4 The IT Domain

Just like competences and competence frameworks, no universally accepted description of the IT domain exists. Several organizations have published classifications of the IT-domain and by doing so, marked out the territory of the IT domain. The largest and probably best known of these organizations is the ACM, the Association for Computing Machinery that has published a taxonomy of IT terms (ACM-1, 2012). Quite recently, a first version of the European foundational ICT body of knowledge has been published as well (ICTBOK, 2015) by the European Union.

The IT-domain is implicitly outlined in IT curricula as well. So a second source of descriptions of the IT domain can be found in IT curricula; a very extensive example can be found in the description given by the Association of Computing Machinery (ACM-2, 2013).

Professionals who are confronted with questions around classification on an almost daily base are librarians. Library classifications have been used and adapted to the state-of-the-art for many centuries. Examples of such classifications are the Dewey Decimal Classification (DDC, 2012) and the Universal Decimal Classification (UDC, 2012). Most countries have their own system(s), for example in our country the 'Nederlandse Basisclassificatie' [2] (NBC, 2004) is used by most scientific libraries.

Other sources that in some way demarcate the IT domain are frameworks that structure the world of IT in relation to the enterprise. The best known example here is the Zachman framework for enterprise architecture (Zachman, 2006). In this framework six different aspect systems in an organization can be modeled on five abstraction levels, ranging from the context of the organization to a detailed description of its technology.

All descriptions of the IT domain have in common that they classify the IT domain along its content. It follows that these classification schemes are simple, using only one axis.

2.5 Mappings

Because there are many different competence frameworks available it is often needed for mutual comparisons to map frameworks onto each other. When mapping one framework upon another, it is desirable to be as complete as possible, meaning first of all that all classes of the source framework are mapped on classes of the destination framework. Secondly, when the source framework is complex, all relations of the source framework should (where possible) be mapped on relations in the destination framework as well.

So a mapping of one framework upon another framework consists of:

- A mapping of the classes of each dimension of the framework upon classes (possibly from more dimensions) in the other framework.
- When the framework is complex: a mapping of the relations between the classes in the framework upon the relations in the other framework.

With the plethora of IT competence frameworks, many efforts have been made to compare competence frameworks and relate the included competence-classes. As discussed in the preceding paragraphs, there is ample discussion on the meaning of competences and competence frameworks are developed from very different perspectives. So the mapping from one framework upon another is not very straightforward and in practice is usually done by experts in the field and validated by other experts (e-CF, 2014). To the best of our knowledge only Lundqvist, Baker & Williams (2011) have build a limited prototype of a system for mapping competence frameworks, applying ontologies and ontology toolsets, but their approach seems to have had no continuation.

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[2]) Dutch basic classification

Since descriptions of the IT domain are essentially simple classifications, a mapping of a complex competence framework like the e-CF is reduced to mapping the classes of the e-CF on the classes as discerned in the descriptions of the IT domain, thereby losing the information described in the proficiency levels.

3 Research Approach

Our research question has led us to use an evaluative research approach. Evaluation is defined by Mertens (2014, p.48) as: "Evaluation is an applied inquiry process for collecting and synthesizing evidence that culminates in conclusions about the state of affairs, value, merit, worth, significance or quality of a program, product, person, policy, proposal or plan…"

The research process started with an initial literature study (summarized in the preceding section) in order to define the concepts used and to embed our research in existing theories. The literature study was followed by a mapping of the 40 competencies as distinguished in dimension 2 of the e-CF (e-CF, 2014) on five different descriptions of the IT domain. The result of this work was a first impression of the way in which the IT domain is covered by the e-CF.

To get more detail, we decided to refine one of the mappings. This refinement was performed by two teams of two IT students from our university, the HU University of Applied Sciences with the teams working *independently* of each other. For the refinement, the (435) knowledge and skills elements that constitute the 4th dimension of the e-CF (2014) have been used. By using two independently working research teams, we were able to analyze the differences in mappings between the teams and from there infer how reliable the mappings have been done.

The research approach chosen is depicted in figure 1.

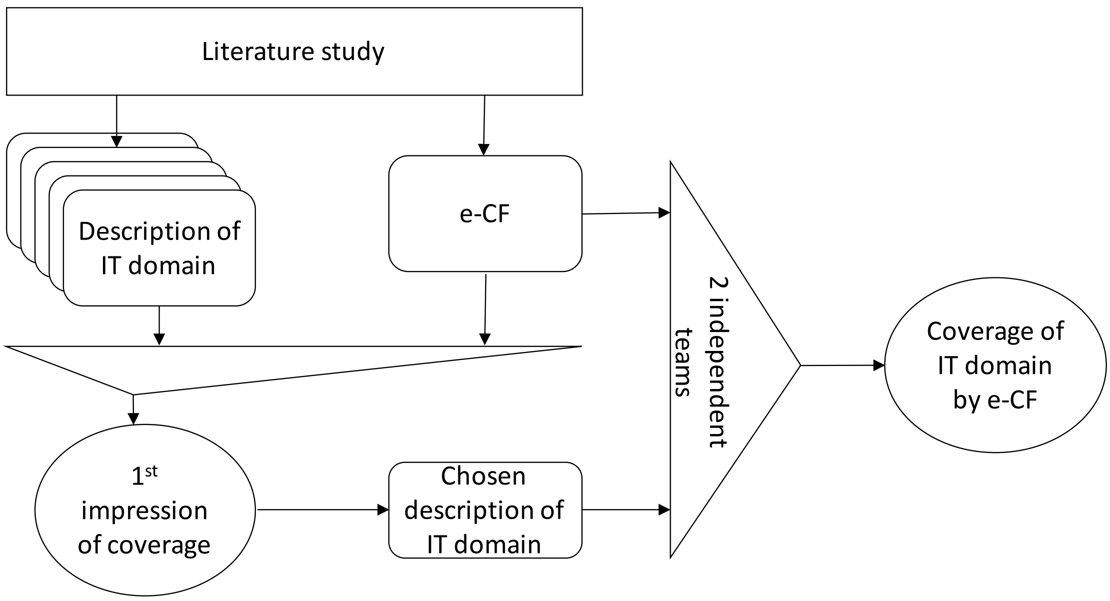

Figure 1: Research process

4 Mapping the e-CF on the domain of IT

4.1 Initial Mappings

In section 2.4 we have argued that descriptions of the IT domain can be obtained from different sources. For our first mappings of the e-CF on the domain of IT, we have used a well-known example from the various sources mentioned in section 2.4, supplemented with the recently published description of the IT domain by the European Union (ICTBOK, 2015);

1. Taxonomy of IT terms (ACM-1, 2012).
2. IT 2013 Curriculum (ACM-2, 2013).
3. Nederlandse Basisclassificatie (NBC, 2004).
4. Zachman Framework (Zachman, 2006).
5. ICT body of knowledge (ICTBOK, 2015).

For the first four descriptions above, the mapping has been done by the authors of this paper. The mapping of e-CF on 5) the ICT Body of Knowledge has been done by its authors (ICTBOK, 2015).

From these mappings, the following preliminary conclusions were drawn:

- The e-CF basically covers the IT domain – albeit on some topics better than on others. Moreover, it covers topics from other domains as well, for example business administration and marketing.
- IT fundamentals and mathematical background are implicitly covered in the competences of the e-CF. This is something to keep in mind when e-CF is used as foundation to assessments (e.g. of IT professionals or students) where the risk is that these topics may be inadequately tested.
- Due to the lack of domain knowledge in the e-CF, some topics have a very broad range. An example is competence B1: Application Development, which covers a wide range from very technical systems to games to administrative systems, etcetera.
- Competence class C (RUN) consists of (only) four competences. This seems rather restricted and competences around security for example are not very comprehensively defined.

From the preliminary research we also learnt that some descriptions of the IT-domain were more useful for our purpose than others. The Zachman framework proved not very suitable as it lacks detail and the various categories are not well-defined. The Nederlandse Basisclassificatie (dating from 2004) was lacking in detail as well and on several topics outdated. The IT 2013 curriculum turned out to be quite usable, but very much tuned to education. So, for our purpose, the best descriptions of the IT-domain were given by ACM's taxonomy of IT terms from 2012 and by the ICT Body of Knowledge dating from 2015. We have chosen to use ACM's taxonomy in the more detailed research as the ICT Body of Knowledge stems from the same source as the e-CF itself, the European Union, and a bias towards the way of thinking underlying the e-CF may be present in this description.

4.2 Detailed Mapping

In the e-CF, a detailed description of every competence is given in dimension 4 where knowledge and skills that relate to the competences, are provided. The 40 competences of dimension 2 are subdivided in 435 knowledge/skills-descriptions in dimension 4. These were compared with the classification of ACM's taxonomy (ACM-1, 2012), consisting of 12 classes on the first level and 82 (sub)classes on the second level. More detailed subdivisions of the taxonomy were used to clarify meanings on this second level.

As stated before, the detailed mapping has been done by two teams of two IT-students each group working independently of one another. For the mappings we used a three-phase approach. In the first phase every team was asked to map one competence of e-CF to the second-level subclasses of ACM's taxonomy. The teams needed approximately two hours and the results were extensively discussed with both groups together to understand the process and create a common understanding of both the e-CF and the ACM terminology.

In the second phase the other 39 e-CF competences were mapped on the taxonomy by both research teams independently. For the mapping the research teams were asked to relate every knowledge/skill element of the e-CF to the terms in the second level of ACM's taxonomy, using a 3-point scale:

0 – no relation present

1 – sometimes, in some domains, related

2 –overall clearly related.

After the mappings of both groups were completely finished (it took the teams around 40 hours each) we organized the third phase: a session to compare the differences in the mappings from the two research teams. From the more than 35,000 comparisons, initially only 4% differed. The different scores were typically found in clusters in a combination of an e-CF competence and an ACM class. These clusters were subsequently discussed to determine the cause of the different mapping ratings. We found that the differences could be explained by slightly different interpretations of the various terms in the taxonomy.

The results of the final comparison are summarized in figure 2. In this figure (with e-CF competences as rows and the first level terms of ACM's taxonomy in the columns) every cell reflects the total score of all knowledge/skills elements from the corresponding competence and from the sub-terms of the corresponding first level term of the taxonomy. Because the number of knowledge/skills elements in the e-CF differs between competences as does the number of sub-terms of each first level term in the taxonomy, these scores were classified in four categories and color coded as explained in figure 3.

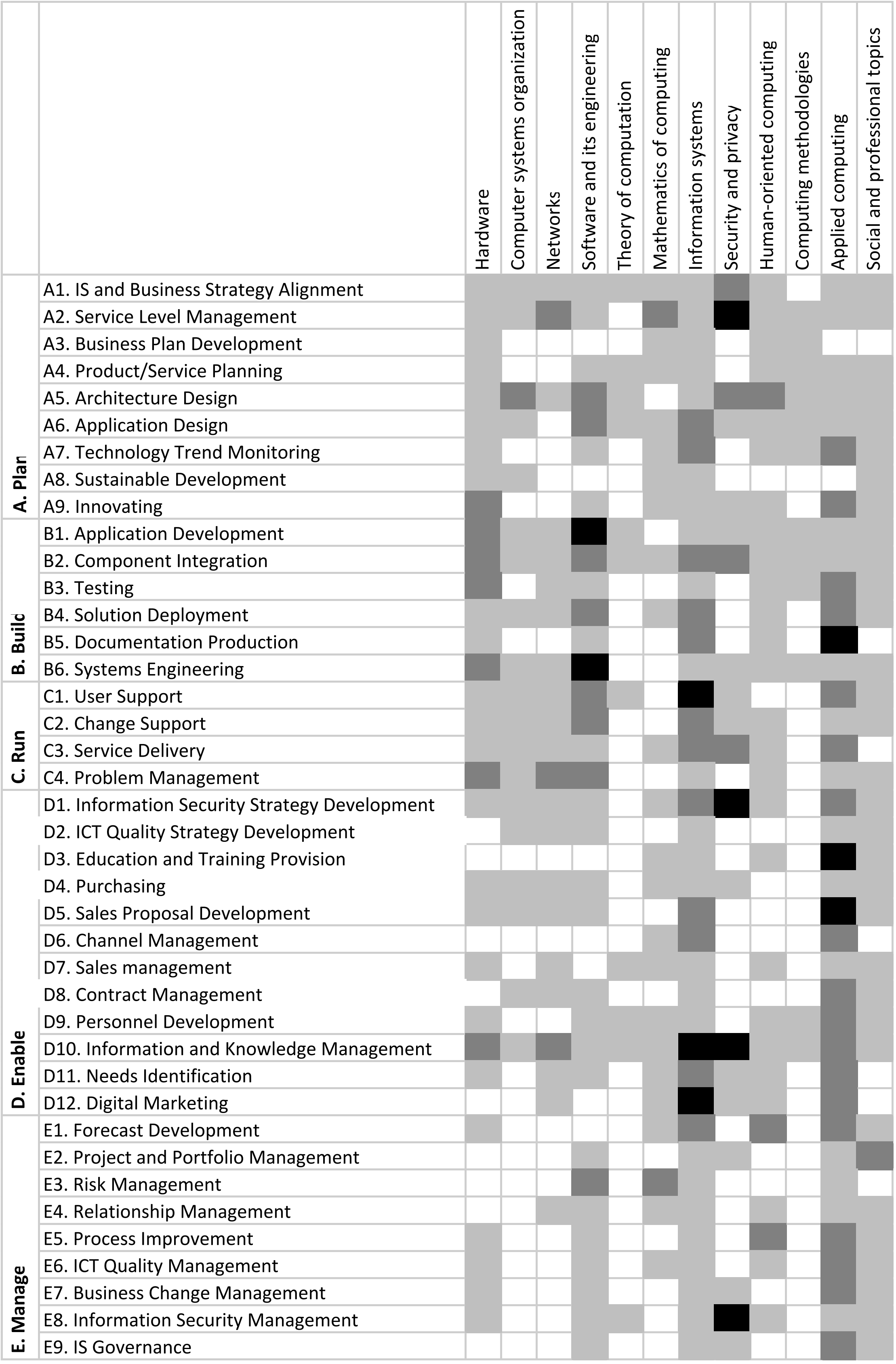

Figure 2: Mapping of e-CF on ACM's taxonomy (legend in figure 3)

	white	The knowledge/skills descriptions for this competence could not be matched to any of the terms in the second level of ACM's taxonomy
	light grey	The knowledge/skills descriptions for this competence could be matched to some (i.e. less than 35%) of the terms in the second level of ACM's taxonomy
	dark grey	The knowledge/skills descriptions for this competence could be matched to various (i.e. between 35% and 70%) terms in the second level of ACM's taxonomy
	black	The knowledge/skills descriptions for this competence could be matched to most (i.e. at least 70%) terms in the second level of ACM's taxonomy

Figure 3: The four classes and their color coding

The results of this detailed mapping support our preliminary conclusions: the e-CF more or less covers the IT domain, but some themes from the IT domain (like 'Theory of computing', 'Mathematics of computing' and 'Computing methodologies') appear only superficially in the e-CF. Remarkable is the low score on 'Social and professional topics' as competences in the e-CF are meant to include attitude aspects as well (e-CF, 2014). This result may well be due to the fact that only knowledge and skills descriptions are present in dimension 4 of the e-CF and attitude aspects are kept implicit in these descriptions.

5 Discussion, limitations and further research

In the preceding paragraph we have shown how the e-CF can be mapped on the IT domain. As a result, we can now reflect upon how meaningful and applicable e-CF as a standard is. For this we use the general classification requirements *completeness, unambiguous* and *orthogonality* as discussed in section 2.

Based on this study we conclude that while the e-CF seems *complete* and adequate in covering the IT domain, there are some themes (like 'Theory of computing', 'Mathematics of computing' and 'Computing methodologies') that appear only superficially in the e-CF. Furthermore, for the description of the competences of IT professionals, some additions to the e-CF could be worthwhile:

- A more explicit occurrence of attitude aspects, especially in dimension 4 of the e-CF.
- A new dimension describing various IT contexts. In this way differences in for example application development in different contexts (like technical, administrative, games, etcetera), can be made visible.

However, we would like to state a word of caution here. While extensions to the e-CF framework might increase its coverage of the IT domain, it might also cause the framework to become overloaded and less usable in practice. As frameworks become more popular and are used by more organizations there is a tendency to expand them and incorporate aspects and wishes of different user groups. This may lead to large and difficult to understand frameworks that are hard to use in practice. Especially now that e-CF is on the road to become a European standard, the maintenance and extension process should be carefully considered.

Regarding how *unambiguous* the e-CF is, we find that although there is room for interpretation on how a competence can be mapped on the ACM taxonomy, in practice the interpretations don't really differ that much (as the 4% differences in 35.000 comparisons has shown). We conclude that the strength of the e-CF in this respect is very high.

The third requirement states that for a complex framework *orthogonality* is required. In other words, every axis of the framework should have a meaning independent of the other axes. Concerning this aspect, we conclude that e-CF is well constructed as the proficiency levels are independent of the competence classes.

Together the requirements, as described above, guarantee that every combination of dimensions in the framework has one and only one meaning. As we have seen there is some room for interpretation but very limited. So while the e-CF might not be a framework in which every combination of dimensions in the framework has one and only one meaning, it comes however quite close.

Looking at the mapping itself, the information present in the proficiency-level descriptions has not been used in our research. Our mapping with its 3-point scale is of a qualitative nature as well. However, when we lay the threshold in the mapping at including only the cells where the descriptions at least match various terms of the taxonomy (dark grey or black in the figure), we found it quite in line with the mapping of the e-CF on the ICT Body of knowledge description (ICTBOK, 2015).

Our research does have its limitations. First of all, our mappings – though they seem quite consistent – rely strongly on the interpretations of various competences and terms and the consistency thereof in the comparisons. In the second place the results are not (yet) validated by other experts with the exception of the mapping of e-CF on the ICT Body of Knowledge (ICTBOK, 2015) that essentially gives the same results as our mappings. The results as summarized in figure 2 should therefore not be seen as absolute, rather they give a qualitative image of the degree to which the e-CF covers the IT-domain.

Finally, the ACM's taxonomy is biased towards a more technical definition of the IT domain and does not do justice to the more business-oriented scope of the e-CF. As stated in the introduction, IT has an enormous impact on traditional business and the orientation chosen for the e-CF may make it easier to adopt in practice. In our opinion, adoption of the e-CF may even be accelerated by stating more explicitly attitude aspects, as the soft skills of the IT professional can make the difference in success or failure of an IT project.

We think the results of our research are encouraging and give a good insight in the strengths and shortcomings of the e-CF. For future research we plan to extend our mapping towards the business aspects of the e-CF and try to relate the e-CF to other competence frameworks by making direct mappings.

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