Zooming in on Competences in Ontology-based Enterprise Architecture Modeling

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Abstract. Organizations must pay close attention to human resource development in order to be successful. Because of this, competence-based approaches have received increased attention, as the demand for qualified people with the right combination of competences establishes itself as a major factor of organizational performance. This paper examines how competences can be incorporated into Enterprise Architecture modeling: (i) we identify a key set of competence-related concepts such as skills, knowledge, and attitudes, (ii) analyze and relate them using a reference ontology (grounded on the Unified Foundational Ontology), and (iii) propose a representation strategy for modeling competences and their constituent elements leveraging the ArchiMate language, discussing how the proposed models can fit in enterprise competence-based practices.

Keywords: Competences · Ontologies · Competence Modeling · Enterprise Architecture

1 Introduction

Given the importance of human performance in business management and the transformation of socioeconomic systems in general, it is not surprising that human resource management, education, and training typically receive a considerable interest. The drive to human development has resulted in advancements in fields such as Vocational Education and Training (VET) and Human Resource Management (HRM). One of these advancements has been the gradual change from content-based to *competence-based* methods, which represents a change in Vocational Education and Training from a supply-oriented to a demand-oriented model [17, 28].

A focus on competences promotes deeper integration of formal education, vocational training, and professional development, which is aligned with lifelong learning strategies [17]. Further, competence-based methods serve to link an organization's future requirements to its Human Resources (HR) programs [10]. Personnel selection, development, and performance monitoring, as well as corporate strategy planning, are all examples of competence-based activities in human resource management [27]. By reviewing staff competences, organizations can conduct self-assessment to improve their

HR programs, revisiting talent recruitment procedures, performance management systems, training and development tools, employee engagement initiatives, and institutional development plans [10].

The importance of competences to the enterprise has motivated past efforts in which key concepts of Competence Management (CM) were incorporated into Enterprise Architecture modeling [5]. In that work, personal competences were conceived of as "dispositions" of individual business actors that are manifested through their behaviour in organizational contexts. A number of patterns for competence representation in *ArchiMate* were proposed, leveraging on the capability construct. This paper builds up from that baseline and identifies and tackles challenges pursuant to "zooming in" on competences (which were considered as black-boxes in [5]).

The literature on Competence Management reveals that it is indispensable to examine the build up of competences in detail. Over the years, competence has been typically conceived of as the result of the interaction of specific *knowledge* and generic *skills* [24], mediated with *attitudes* [26]. Personal traits, mindset, patterns of thinking, and tacit knowledge are also considered by some authors to be part of competence [8]. While these terms are pervasive in the Competence Management literature, their precise definition has remained elusive. The terms are frequently used interchangeably and are sometimes confused with "competence" itself [26, 29].

We argue that conceptual analysis of these notions and their relations is key to their adequate representation in Enterprise Architecture (EA) models. Domain-adequate representations are, in turn, key to support the use of EA models in competence-based practices. We approach the representation of competence elements in this paper by positioning the notions of competence, skill, knowledge, attitude and other personal characteristics through a reference ontology. The reference ontology is then used as a starting point to the representation of competences alongside their constituent elements in *ArchiMate*.

This paper is further structured as follows: Section 2 briefly reviews the relevant literature on competences and competence management, stating the key conceptual challenges for "zooming in" on competences, which involves the relations between competences, knowledge, skills, attitudes, and other characteristics. An ontology for these elements is offered in Section 3 by specializing the notion of "disposition" in the Unified Foundational Ontology (UFO) [13]. The representation of competence elements in examined in the *ArchiMate* language in Section 4. Section 5 discusses related work. Finally, Section 6 summarizes our effort and proposes a research agenda, which includes the integration of competence management with other key architectural domains of Enterprise Architecture.

2 Competences

Competence[1] is the general ability to perform well a set of mastery tasks [26]. It is not enough for an individual to have a variety of specific skills for this. Mastery of skills or knowledge does not ensure success in complex and unpredictable environments [29].

[1] We adopt in this work the term "competence" to refer to an individual's performative ability, and refrain from using the term "competency".

In addition to skills, the individual must have a sufficient understanding of the domain in question (knowledge) as well as know how to act appropriately in the context (attitude) [26]. In order to be efficient and effective in such situations, the individual must be able to integrate the most appropriate skills and knowledge for it [29]. As a consequence of this, various authors define competence as a combination of knowledge, skill, and attitude [7, 20, 24]. Competences, in other words, are highly valued qualifications that are accountable for the effective application of skills and knowledge in specific and complex contexts [29].

2.1 Skills and Competences

In general, *skills*, not unlike competences, allude to the capability to perform actions. The literature provides different definitions for skills emphasizing different aspects of it. For example, Rodriguez [27] defines a skill as the ability of an individual to perform a task (discrete unit of work) well. Esposto [9] defines it as a set of general procedures that underlies the application of knowledge in a domain. Paquette [24] defines skills as processes that act on knowledge in an application domain [24].

There is no agreement on the best criterion for distinguishing competences and skills [29]. One existing distinction is the level of ability awareness. Competences would be more "conscious", while skills would be more "automatic" [29]. However, this distinction is insufficient because conscious actions occur with skills as well [29].

The level of complexity is another criterion that is invoked to differentiate competences and skills. Competences are considered more complex in this case than skills. Indeed, authors argue that skills *structure* competences [24, 29]. Competences can be made up of sub-competences, forming an internal hierarchical structure inherent in the individual. In this sense, competence is a complex entity. That is, a competence can be formed by others, which can be formed by others, and so on. As a result, this internal hierarchical structure can be formed by many levels of sub-competences [29]. The *basis* of such an internal hierarchy, however, has not been well understood. Competence decomposition only occurs up to a certain level, where the "basic competences" are. Basic competences are divided into skills after this level. In this regard, it is unclear where basic competences end and skills begin [29]. Even skills can also be divided into different levels, until reaching the "basic skills".

Some Competence Models allow sub-competences or skills that make up a competence to be represented. However, as previously stated, the line between basic competence and skill is not always evident. Due to their similarities, the concepts of competence and skill are frequently misunderstood in definitions and representations. As a result, an important goal of a reference ontology for this domain is to clarify the similarities and differences between the concepts of competence and skill, settling how to position those two notions for a certain context of usage.

2.2 Knowledge

Internal representations of facts, principles, or theories in a specific domain are typically associated with "knowledge" [29]. It is the cognitive outcome of assimilation of concepts, ideas, or figures related to a specific topic [26]. Knowledge is linked to a specific person,

the bearer, then it is difficult to transfer and assimilate [4]. Knowledge is assimilated when it becomes a part of the bearer's internal structure. As new information or facts are added, the structure changes [30]. This internal structure is not distinctive to the bearer but is integrated into the internal structure of abilities [30]. Indeed, such internal structures (of knowledge and skill) interact in practical applications and problem-solving [19]. Despite the fact that it changes over time [19], knowledge is a static (passive) entity [29]. It is stored in memory and retrieved using cognitive skills (mental processes) [29].

Many knowledge definitions are similar to skill descriptions as a result of learning. Some authors even consider skills to be a sub-type of knowledge. According [19], skills represent an individual's "practical knowledge" gained through experience. While an individual's interpretations and facts are known as declarative knowledge, the skills (what an individual knows how to do) are known as procedural knowledge [19]. Authors include that skills and knowledge are represented in a similar manner in human mind, via an interconnected internal structure [19].

Understanding an individual's knowledge in the context of CM is important for better understanding their competence. This is particularly useful during the *gap analysis* and *competence assessment* steps. Competence models, which represent a professional's knowledge, can aid in this task. However, confusion between the concepts of knowledge and skill can have an impact on model quality, making it difficult to model knowledge and skill clearly. Despite the similarities described above, skills and knowledge have subtle differences that can interfere with modeling. As a result, a reference ontology for this domain should provide a solid definition of knowledge and clarify the distinction between knowledge and skill.

2.3 Attitudes

In some definitions, attitudes are generally associated with an individual's behavior [20, 24]. Others associate them with personality traits or the professional's psychological and emotional nature [26]. Attitude is a tendency to act (or feel) in a given situation [18]. It is based on assumptions, values, and beliefs, so they are non-neutral with respect to actions [18]. In general, definitions of attitude take into account the following characteristics: (i) mental state; (ii) values (beliefs, emotions); and (iii) predisposition to act or behave [1]. That is, it is a concept that is dependent on its context: a situation, an object, or a person. As a consequence, attitude is a disposition toward a specific phenomenon and can be considered a reaction to the context (object, person, or situation) [1]. This type of reaction is bipolar, so it may or may not be beneficial (positive or negative) to the environment in which it is found [1].

Attitudes are regarded as an important aspect of competences, and are included in many competence definitions as one of the key 'KSA' elements (Knowledge, Skills and Attitudes). In contrast to skills and knowledge, attitude is a more general characteristic that is not tied to a specific task or domain [26]. Because they have certain behavioral impact, attitudes are frequently confused with skills, particularly soft skills [20]. Again, as in the case of skills and knowledge, a reference ontology for this domain should clearly position attitudes with respect to the other elements of competence.

2.4 Other Characteristics

Although competence is commonly defined as a set of attitudes, skills, and knowledge, authors consider further types of elements to be components of competences. Personal traits, behavior, mindset, patterns of thinking, and tacit and explicit knowledge are considered by some authors to be part of competence [8]. This is recognized also by Westera [29], for whom competences have additional elements that are not clearly defined. According to Miranda et al. [20], competences are also formed by a set of personal characteristics required to perform tasks in a specific context, leading the authors to consider the KSAO model, a variation of the KSA model that includes "Other Characteristics" as a fourth element to define competence.

According to Westera [29], task analysis is insufficient to establish competences; instead, the individual's characteristics and experience must be considered. Le Deist and Winterton [17] emphasize the importance of focusing on the individual rather than their conduct. The authors explain that, in addition to performance, it is critical to look at traits, motives, attitudes (or values), and knowledge, among other things. Some KSA elements (attitude and knowledge) are considered personal characteristics by the author. Messick [19] extends on this point by stating that the psychological, emotional, social (environmental) situation, and even biomedical information must all be considered.

All of these characteristics, as well as behavior (performance, tasks, and outcomes), are evidence of an individual's competence. Hence, they are critical in the Competence Assessment task, which is one of the most demanding in the CM context, specifically measurement, both quantitative and qualitative, because it entails giving value to something that cannot be fully observed.

3 Ontological Analysis of Competence-Related Elements

We explore the multi-faceted phenomenon of competence by proposing a reference ontology for competence and its constituent elements. The issues discussed in Section 2 help us to identify focal points for this effort, and ultimately relate competences, knowledge, skill, attitudes and other human characteristics in a coherent representation.

3.1 Baseline

We build up on the work discussed in [5], which used the Unified Foundational Ontology (UFO) [13] to examine competences from an external perspective, not zooming in on its constituent elements. Competences are considered as "dispositions", which, in a nutshell, are objectified properties inherent in an object (or agent) which may manifest themselves in certain situations through events (or actions). (They are also called "powers" in the philosophical literature [21].)

The domain-independent elements we reuse from UFO are shown with a UML class diagram in Figure 1. Concrete individuals are partitioned into perdurants (also called *events*), endurants and situations. *Perdurants* are *individuals* who occur in time (i.e. activities, actions, tasks, processes). *Endurants* are individuals that persist in time while retaining their identity (i.e. people, organizations, projects, cars). *Endurants* include

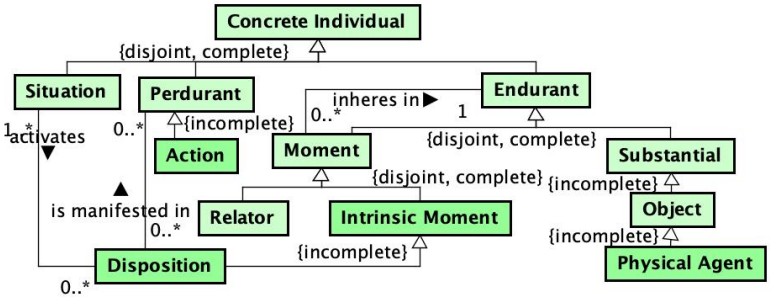

Fig. 1. UFO Fragment (used concepts highlighted)

moments and *substantials*. *Moments* are reified properties that *inhere in* an *endurant* (termed its bearer), on which they are existentially dependent. As endurants, they have a lifecycle of their own, and can be created, destroyed or otherwise change qualitatively in time.

Of special interest to us in this work are those moments called *dispositions*. *Dispositions* are intrinsic moments that can be manifested through the occurrence of *events* (possibly agents' actions, such as Anna's speaking English). In *situations* where *dispositions may manifest*, they are said to be "activated" (e.g., when a magnet is close to some ferrous material, or when Anna is prompted to introduce the topic of a meeting). The literature discusses a number of important features of dispositions; they may fail to manifest when enabled, they may be manifested in tandem with other dispositions in complex events, they may reinforce or cancel each other [21,22]. Reifying (i.e., objectifying) them puts them at the center of our efforts as first-class citizens. As endurants, they can themselves bear moments, and change qualitatively while retaining their identity through time [12].

Figure 1 also shows a few concepts from the UFO-C layer of UFO [14] which are relevant here. *Physical agents* are those objects that, in constrast with non-agentive *objects* bear *intentional moments* such as *beliefs desires* and *intentions* (omitted from the figure). They are capable of *actions*, which are those events that are performed intentionally by *agents*.

3.2 Elements of Competences

In [5], *personal competences* are defined as *dispositions* inhering in a physical agent, with tasks, actions, or behaviors considered as manifestations of those dispositions (*competence manifestations*). The *competence context* that activates the *personal competence* is considered a kind of *situation*. We take this view as a starting point, and extend it to incorporate the internal elements of competence (skills, knowledge, attitudes, etc.), anchoring these elements in the foundational concepts.

Skills and competences as human capabilities. Regarding the skill concept, there are some parallels between it and the definitions of competence [26]. Some authors even

argue that such concepts have the same meaning in essence. Competence is conceptually considered a skill sub-type in some cases [29]. Even among those who believe that competence and skill are distinct concepts, there are many similarities between them. In this sense, both are regarded as human abilities that enable satisfactory task performance [26]. Thus, both skill and competence are inherent abilities in a person, the bearer, that enables the performance of specific actions' types. That is, they represent an individual's "know-how". Aside from this fundamental similarity, there are other comparable features in the definitions of these concepts. Both are abilities that can be learned (formally or informally) and developed through practice [19, 30]. In this sense, skill and competence can be used to learn new abilities via the transfer mechanism [19, 26, 30]. In terms of structure, there are also some similarities between skills and competences. Both have a hierarchical structure, according to some authors [26, 29]. As a result, they can be aggregated or combined at various levels. Thus, simpler skill/competence forms more complex skill/competence. As a consequence, the complexity of skill and competence can also vary. Another similarity between these concepts is their relationship with the context. Both are associated with a context, environment, area, or domain [26, 29]. In this regard, competence and skill can be more generic (domain-independent) or more specific (domain-dependent) [26, 29]. Skills and competences frequently rely on favorable conditions to manifest. That is, skills and competences depend on other properties (internal or external) to manifest themselves more effectively. Knowledge, mental states, attitudes, feelings, and so on can all aid in the proper manifestation of a skill or competence, for instance. Finally, in addition to the aforementioned similarities, some authors argue that skills and competences involve similar domains of an individual. According to them, both are related to the bearer's affective, social, physical (or operational), cognitive, and meta-cognitive domains [17, 26]. In order to capture the common features of skills and competences, we introduce the notion of Human Capability as shown in Figure 2. Skills and competences are considered sub-types of the more general notion of Human Capability, which in turn are dispositions inherent in a Person.

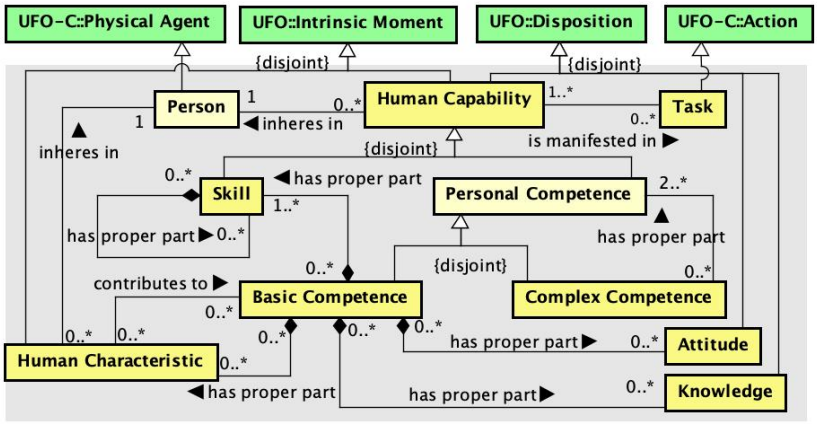

Fig. 2. Competence Element's Definition (new concepts highlighted)

Human Capability encompasses all human abilities, from those that are innate (inherited) to those that can be learned (formally or not) and is manifested through a task (an action with some goal or a work unit). The task in this work is regarded as the smallest unit of labor. In other words, it is a discrete unit of work that contributes to the production of an output or the achievement of a goal [27].

Competences versus Skills. In this current work, the main distinction between skills and competences is the structural aspect as revealed by the specialized whole part relations in Figure 2. Competences are formed by knowledge, skills, attitudes and other human characteristics, whereas skills are formed only by other simpler skills. In this work, a competence is made up of at least one skill that is linked to one or more other competence's elements. Based on [26], another adopted criterion to distinguishes skill from competence is the mode of manifestation. Competence is associated with one or more complex tasks, whereas skill is associated with a simple task (basic unit of work), as in [26]. The whole part relations put forward a hierarchical view of competences. Complex Competences are those composed of other competences; Basic Competences are those at the bottom of the competence decomposition hierarchy, whose elements follow the KSAO model. Skills can also be structured hierarchically for a comprehensive conceptualization.

Knowledge. In this context, knowledge is defined as a justified true belief [16]. Knowledge, while assisting in the realization of skills, differs from skills in that it is a static entity registered in the individual's memory. It is related to the person's knowledge of information, facts, and concepts. It is produced as a result of internal (mental) information processing. Skills, on the other hand, manifest themselves through (cognitive or psycho-motor) tasks and are developed through practical experiences. In this way, knowledge, despite representing external facts or concepts, is existentially dependent on the bearer. Individual knowledge, as a type of belief, can be considered a subjective entity that is difficult to measure or quantify, despite the fact that it may have attributes. Furthermore, knowledge is a mental property that is inherent in the individual that can lead to action. It is manifested alongside other forms of dispositions such as skills to manifest itself in tasks, forming *reciprocal* or *mutual* activation partners [22].

Attitudes. Despite the fact that it is manifested through actions, gestures, postures, and so on, attitude differs from skills in that it is not manifested through tasks. Attitude, on the other hand, can be task-related. For example, a responsible attitude can be present during a developer's completion of the task of fixing a bug in software; an empathetic attitude can be present during the task of negotiating project scope with the client. Attitude in the context of this work is considered a sub-type of *Disposition*, because it is a proclivity to act and behave. Again, like knowledge, it is manifested alongside other forms of dispositions, forming *reciprocal* or *mutual* activation partners [22] with skills and knowledge.

Other Human Characteristics. Human characteristics are particular to an individual and form part of their personality. Some of these characteristics include objective (or measurable) attributes (e.g., sex, age), while others are subjective (non-measurable),

such as the individual's motivations, worldviews, values, and beliefs. As previously stated, such human characteristics are regarded in this work as a subtype of *Intrinsic Moment*. A concept of this type includes both objective (measurable) and subjective human characteristics and could be part of a personal competence. As an intrinsic moment, human characteristics can be categorical (e.g. age, gender, etc) or dispositional (e.g. personality traits). Based on the categorical base of the disposition, the former contributes to competence formation [6]. As illustrated in Figure 2, the latter are a proper part of the competence. Furthermore, some human characteristics can be included in the competence context, activating the competence manifestation.

4 Well-Founded Competence Representation

Based on the ontological distinctions presented in the previous section, we define an ArchiMate language pattern in this section, with no changes to the ArchiMate metamodel. The well-founded representation is proposed to allow modeling of competence and its elements (knowledge, skill, attitude) in the EA context, supplementing the representation proposed in [5]. To summarize, [5] represents: (i) *Person* with a *Business Actor*; (ii) *Personal Competence* with a *Capability* Element related to a *Business Actor*; (iii) *Competence Manifestation* with any ArchiMate *Behavioral Element* related to a *Capability* Element, and; (iv) *Competence Context* with *Plateau* or *Location* Elements related to a *Capability* Element.

Based on this, the elements of competence are represented as follows. *Skill* is represented by the *Capability* Element related to: (i) another *Capability* Element representing a *Personal Competence* with a composition relation, or (ii) a *Business Actor* representing a *Person* (the skill bearer). *Knowledge* is represented by a *Meaning* Element that is linked to a: (i) *Capability* Element that represents a *Personal Competence*, or (ii) *Business Actor* that represents a *Person* (the knowledge bearer). *Attitude* is represented by the *Value* Element related to: (i) *Capability* Element, which represents a *Personal Competence*, or (ii) *Business Actor*, which represents a *Person* (the attitude bearer). Aside from the fact that the ontological model does not establish any relationship between the competence's elements, they could also be linked using the *ArchiMate*'s *Association* relation. This is an appropriate way of representing the relation among competence's element.

Figure 3 depicts a high-level overview of the language pattern. As shown in Figure 3, John (Person) is a junior developer that works as a front-end developer at a software organization. In this context, he possesses the (complex) competence of full-stack development, which is made up of two (basic) competences: back-end development and front-end development. As shown, Java and SQL coding skills are among John's back-end competences. John's front-end competence includes *HTML*, *CSS*, and *Javascript* (JS) coding skills, besides user interface (UI) prototyping one. Its competence also includes John's responsibility attitude besides knowledge of quality criteria and of UI heuristics.

As the *Plateau* element indicates, the model in Figure 3 represents John's current situation. Because it represents the current state of individual competences in the organization, this type of model is useful in the Competence Mapping stage of the CM process. On the other hand, it is also possible to represent through this language pattern

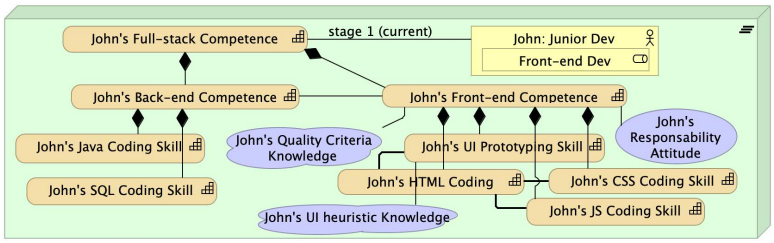

Fig. 3. Skill, Knowledge, and Attitude representation (Current Stage)

the desired competences of the individual for the organization. For this, it necessary specify through a *Plateau* element. This type of diagram is useful for better understanding the desired competences during the Competence Identification step. Figure 4 depicts this situation, where John's desired competences for organization are represented. As shown, it is desirable for the organization that John evolves technically (hard skills) and gains specifically the coding review skill (highlighted one). As a result, John will be able to review the web form code for user story 23 (highlighted one).

In terms of the manifestation of this specific competence, the skills are in charge of the completion of basic tasks (discrete units of works). As shown, *HTML* and UI prototyping skills are responsible for the coding of web form fields coding and web form prototyping manifestation, in context of user story 23 (US23). While these skills are associated with basic task manifestation, John's front-end competence is related to the manifestation of the entire web form development process, which is related to US23.

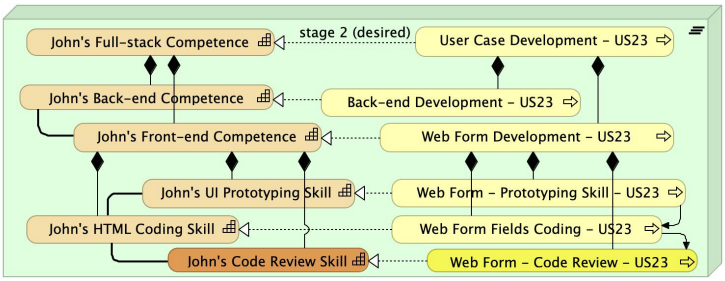

Fig. 4. Skill representation (Desired Stage)

Following Competence Identification and Mapping, one important step in the CM process is to compare the desired and current organizational states using the Gap Analysis activity. This comparison can concentrate on various aspects, such as the professional's technical or behavioral evolution. Figure 5 depicts a comparison focusing on John's soft skills evolution. In this case, in order for John to advance his front-end competence, he must acquire new soft skills such as communication and problem-solving skills, in

addition to the previously mentioned code review skill. In addition to these skills, it is wanted that John will develop a collaborative attitude toward code review (to assist in reviewing college codes). It is also desired that he gain new knowledge about coding best practices and code review techniques.

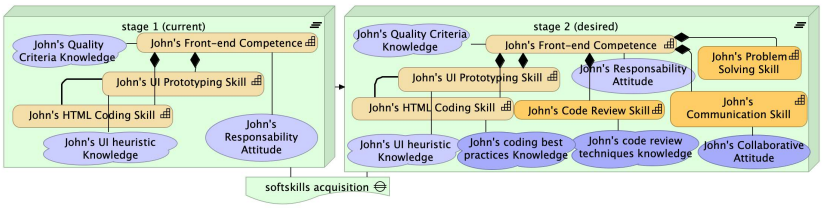

Fig. 5. Competence Elements detailing in Gap Analysis

5 Related Works

Competence models range from simple competence representations to more semantically rich and sophisticated representations [25]. Competence management approaches began to use standardized models, such as XML-based ones, to support specific technological tasks such as data integration and exchange. These models then evolved into more complete conceptual models. Recently, ontology-based models have become more prevalent in CM approaches, incorporating more semantics into competence models [15]. They have been used for a variety of purposes, the majority of which are related to business and education. Some of these works are discussed below.

In the ontology of Zaouga et al.'s [31], knowledge and skill are considered sub-types of competence rather than elements. The ontology does not cover attitudes. In its place, the authors use the behavior concept with a similar meaning. Paquette's ontology [24] also includes skill and knowledge, but not attitude. In this case, knowledge and skill are components of competence. [24] also connects the concepts of skill and knowledge. Skills are applied to knowledge entities in this case. Skills are classified in the ontology based on taxonomies and complexity levels, and they are also measured using indicators. Miranda et al.'s [20] also incorporate knowledge, skill, and attitude into their model. In its structure, competence consists of these elements. As stated in [20], knowledge and skill are also related concepts. This ontology takes into account not only skill classification but also knowledge and attitude.

In contrast to those works, the proposed ontology treats competence and skill as a compound entity. As a result, they could be represented at various levels of abstraction. They are dispositional concepts, and types of Human Capability, that can manifest themselves through tasks. Knowledge and attitudes share this dispositional nature and can manifest together with tasks through actions, posture, and so on. Aside from the detailed and well-founded representation of competence, the link between competences and Enterprise Architecture is another distinguishing feature of this work.

Some other works such as [3, 23] have also explored foundational ontologies in EA modeling. Both employ UFO to conduct ontological analyses of two concepts closely related to competence: capability and service. [23], for example, views service delivery as the manifestation of competences. [3], on the other hand, conducts an ontological analysis of Capability and is also related to the concept of Competence. [3] briefly discusses the definition of competence based on capability; in the current work, we adopt and expand on that analysis. As discussed here, competences can be placed in the so-called capability bundles [3], connecting individual-level capabilities (competences) with organizational capabilities.

6 Final Remarks and Discussion

The study presented in this paper aimed to improve competence modeling in the context of Enterprise Architecture by using a reference ontology as a semantic foundation. The understanding of skills, knowledge, attitudes, and other characteristics allowed us to zoom in on an individual competence, allowing for a detailed competence representation in the context of Enterprise Modeling.

We investigated the support of Competence Management activities with Enterprise Architecture models with the goal of improving personal competence understanding. From the standpoint of competence detailing and decomposition, the proposed competence representation strategies make it easier to implement Competence Management in EA. The model representation using *ArchiMate*, on the other hand, contributes a set of possibilities to enhancing the Competence Management practice. This distinguishes the current work from other ontology-based competence works in the literature.

As a result, the proposed representation can aid in essential Competence Management (CM) activities such as competence mapping, identification, and gap analysis. In this sense, the proposed representation patterns facilitates CM activities by visualizing modeling competences from various perspectives. It enables the detailing of individual competences in these various representations, assisting with a deeper comprehension of the individual skills, knowledge, and attitudes that comprise these competences. This detailed vision aids in many CM activities such as competence comparison, planning, and assessment, to name a few.

Future research could open up on the concept of competence by investigating how the competences of different individuals can be combined to form organizational and collective capabilities. This study would delve deeper into how organizational capabilities emerge from personal competences. Capabilities are not created by simply combining competences. The combination of high proficiency and competence does not guarantee the formation of a high-performance team. It is a very complex and difficult subject that deserves more investigation. In this regard, we see an opportunity to incorporate *General System Theory* (GST) concepts into the ontological foundation in order to better represent the phenomena of evolution, emergence, and composition in the context of Enterprise Architecture. In this context, we see an opportunity to study theories of dispositions in order to better understand how competences can be related and combined.

We also see the need to develop case studies should be used to validate the proposed competence representation patterns. Although ontological analysis provides the

foundation for a well-founded representation (as used here, the foundation incorporates advances in Formal Ontology, Philosophical Logics, Philosophy of Language, Linguistics, and Cognitive Psychology [12]), the pragmatics of a representation in its usage context should be thoroughly assessed. Efforts in this sense have already been made for other UFO-based representation schemes, such as [11], [23].

Another area of future research concerns the relationship between competences and other *ArchiMate* perspectives, such as Motivation Elements. In this case, the ontological analysis could include other UFO concepts related to intentions, such as Goal and Proposition, which are related to the organization's strategic goals [2].

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References

1. Altmann, T.K.: Attitude: a concept analysis. In: Nursing forum. vol. 43, pp. 144–150. Wiley Online Library (2008). https://doi.org/10.1111/j.1744-6198.2008.00106.x
2. Azevedo, C.L.B., Almeida, J.P.A., van Sinderen, M., Quartel, D., Guizzardi, G.: An Ontology-Based Semantics for the Motivation Extension to ArchiMate. In: 15th IEEE Int. EDOC Conference. pp. 1–10. IEEE (2011). https://doi.org/10.1109/EDOC.2011.29
3. Azevedo, C.L.B., Iacob, M., Almeida, J.P.A., van Sinderen, M., Pires, L.F., Guizzardi, G.: Modeling resources and capabilities in enterprise architecture: A well-founded ontology-based proposal for ArchiMate. Information Systems **54**, 235–262 (2015). https://doi.org/10.1016/j.is.2015.04.008
4. Brown, J.S.: Learning in the digital age. In: The Internet and the university: Forum. vol. 71, p. 72 (2001)
5. Calhau, R.F., Azevedo, C.L.B., Almeida, J.P.A.: Towards Ontology-based Competence Modeling in Enterprise Architecture. In: 25th IEEE Int. EDOC Conference (EDOC 2021). IEEE (2021). https://doi.org/10.1109/edoc52215.2021.00018
6. Choi, S., Fara, M.: Dispositions. In: Zalta, E.N. (ed.) The Stanford Encyclopedia of Philosophy. Metaphysics Research Lab, Stanford University, Spring 2021 edn. (2021)
7. Draganidis, F., Chamopoulou, P., Mentzas, G.: A semantic web architecture for integrating competence management and learning paths. Journal of Knowledge Management **12**(6), 121–136 (2008). https://doi.org/10.1108/13673270810913667
8. Draganidis, F., Mentzas, G.: Competency based management: a review of systems and approaches. Inf. Manag. Comput. Secur. **14**(1), 51–64 (2006). https://doi.org/10.1108/09685220610648373
9. Esposto, A.: Skill: An elusive and ambiguous concept in labour market studies. Australian Bulletin of Labour **34**(1), 100–124 (2008), https://EconPapers.repec.org/RePEc:fli:journl:26132
10. Gangani, N., McLean, G.N., Braden, R.A.: A competency-based human resource development strategy. Performance Improvement Quarterly **19**(1), 127–139 (2006)
11. Griffo, C., Almeida, J.P.A., Guizzardi, G.: Conceptual Modeling of Legal Relations. In: 37th Int. Conf. Conceptual Modeling (ER 2018). Lecture Notes in Computer Science, vol. 11157, pp. 169–183. Springer (2018). https://doi.org/10.1007/978-3-030-00847-5_14

12. Guizzardi, G., Wagner, G., Almeida, J.P.A., Guizzardi, R.S.S.: Towards ontological foundations for conceptual modeling: The unified foundational ontology (UFO) story. Applied Ontology (Online) **10**, 259–271 (2015). https://doi.org/10.3233/AO-150157
13. Guizzardi, G.: Ontological Foundations for Structural Conceptual Models. No. 15 in Telematica Instituut Fundamental Research Series, Telematica Instituut, The Netherlands (2005)
14. Guizzardi, G., Wagner, G.: Towards ontological foundations for agent modelling concepts using the unified fundational ontology (UFO). In: Agent-Oriented Information Systems II, pp. 110–124. Springer Berlin Heidelberg (2005). https://doi.org/10.1007/11426714_8
15. HR-XML Consortium: Competencies 1.0 (measurable characteristics) recommendation 2001-oct-16 (2016), http://xml.coverpages.org/HR-XML-Competencies-1_0.pdf
16. Ichikawa, J.J., Steup, M.: The Analysis of Knowledge. In: Zalta, E.N. (ed.) The Stanford Encyclopedia of Philosophy. Metaphysics Research Lab, Stanford University, Summer 2018 edn. (2018)
17. Le Deist, F., Winterton, J.: What is competence? Human Resource Development International **8**(1), 27–46 (2005). https://doi.org/10.1080/1367886042000338227
18. Maze, J.R.: The concept of attitude. Inquiry **16**(1-4), 168–205 (Jan 1973). https://doi.org/10.1080/00201747308601684
19. Messick, S.: The psychology of educational measurement. Journal of Educational Measurement **21**(3), 215–237 (Sep 1984). https://doi.org/10.1111/j.1745-3984.1984.tb01030.x
20. Miranda, S., Orciuoli, F., Loia, V., Sampson, D.: An ontology-based model for competence management. Data & Knowledge Engineering **107**, 51–66 (Jan 2017). https://doi.org/10.1016/j.datak.2016.12.001
21. Molnar, G., Bradley, N.: Powers: A study in metaphysics. Clarendon Press (2003)
22. Mumford, S., Anjum, R.: Getting Causes from Powers. Oxford University Press (2011)
23. Nardi, J.C.: A Commitment-based Reference Ontology for Service: Harmonizing Service Perspectives. Ph.D. thesis, Federal Univ. of Espírito Santo (2014)
24. Paquette, G.: An ontology and a software framework for competency modeling and management. Educational Technology and Society **10**(3), 1–21 (2007), http://www.ifets.info/journals/10_3/1.pdf
25. Rezgui, K., Mhiri, H.: Modeling competencies in competency-based learning: Classification and cartography. In: 2018 JCCO Joint Intl Conf ICT in Education and Training, Intl Conf Computing in Arabic, and Intl Conf Geocomputing (JCCO: TICET-ICCA-GECO). IEEE (Nov 2018). https://doi.org/10.1109/icca-ticet.2018.8726208
26. Rodrigues, M., Fernández-Macías, E., Sostero, M.: A unified conceptual framework of tasks, skills and competences. Tech. rep., JRC Working Papers Series on Labour, Education and Technology (2021)
27. Rodriguez, D., Patel, R., Bright, A., Gregory, D., Gowing, M.K.: Developing competency models to promote integrated human resource practices. Human Resource Management **41**(3), 309–324 (2002). https://doi.org/https://doi.org/10.1002/hrm.10043
28. Sampson, D., Fytros, D.: Competence models in technology-enhanced competence-based learning. In: Handbook on Information Technologies for Education and Training, pp. 155–177. Springer Berlin Heidelberg (2008). https://doi.org/10.1007/978-3-540-74155-8_9
29. Westera, W.: Competences in education: A confusion of tongues. Journal of Curriculum Studies **33**(1), 75–88 (2001). https://doi.org/10.1080/00220270120625
30. Wood, R., Power, C.: Aspects of the competence-performance distinction: Educational, psychological and measurement issues. Journal of Curriculum Studies **19**(5), 409–424 (Sep 1987). https://doi.org/10.1080/0022027870190503
31. Zaouga, W., Rabai, L.B.A., Alalyani, W.R.: Towards an ontology based-approach for human resource management. Procedia Computer Science, vol. 151, pp. 417–424. Elsevier (2019). https://doi.org/10.1016/j.procs.2019.04.057