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Conditions, Requirements, and Guidelines to a Universal, Integrative Model of Digitally Operable Competence Representations

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Abstract: This paper addresses the strategic need to define and establish a global digital infrastructure for a distributed, integrative competence management system. It summarizes and details hitherto research and conception of the author since 2004 and intends to blaze a trail for future strategic research transversal to disciplines, contexts, and stakeholders. Essential element of this system is an operative, distributed, pervasive, and semantic competence representation model. Conditions for such a model are described using a competence definition, a reference model with a framework of system functions, and a plan for further activities. Functional requirements regarding type and composition of a representation model are analyzed, and guidelines for a model proposed.

Keywords: integrative transversal competence management framework, competence model, competence definition, digital representation, syntax formulation, semantic network, distributed ontology.

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1 Introduction

In his German dissertation from 2006 [Da06], the author of this paper (under his previous name *Matthias Patrick Meyer*) assessed the need for an *Integrative Competence Management System* as a universal, machine-readable infrastructure for pervasive operationalization of global life-long learning. He further proposed a reference model, a framework of system functions, and first concepts for models, use cases, and tools for these functions. Ten years later, the working group *strategic competence management* (referred to as *SCM*) of the *Gesellschaft für Wissensmanagement (GfWM)*[2] published a working paper [DRS16] that revised, confirmed, and refined this approach[3] with reference to recent societal developments. The SCM concluded with a call to action to establish such a system. Following up on this, this paper intends to spark and internationalize a discussion about the composition of a universal, integrative model of digitally operable competence representations.

2 Conditions

2.1 Definition

[Da06, p. 3-9] presents an overview of prevalent definitions of *competence* and other related terms. As most common aspects, a competence is a personal, self-organizing disposition to act in a specific context to solve a problem or fulfill complex requirements, as a result of a learning process. Restrictions from these definitions rule relevant elements out that could be subject to an integrative, universal management system. But *competence* is common linguistic use for a wide range of learning outcomes or skills: Reviews of various initiatives by Weinert, Trier, and Oakes revealed a use of terms related to competence (including skill, qualification, literacy, etc.) as being widely arbitrary, inconsistent, imprecise, and interchangeable, as referred to in the final report of the project *Definition and Selection of Competencies (DeSeCo)* [RS03, p. 41]: "Minimal or no attention is devoted to defining various the notions or distinguishing among them." DeSeCo attributes this *conceptual pragmatism* to a lack of single use, a broadly accepted definition, or a unifying theory (ibid.). However, it might as well be interpreted as an apparent societal need for a superordinate catch-all concept not requiring accurate discrimination between detailed notions: In essence, *competence* is an abstract concept and not objectively verifiable (just as related concepts like knowledge, qualification, experience, skill, ability, education, behavior, or value). Its definition is inherently nominal (not real), modelling a specific perspective on a ubiquitous concept in human life, but an integrative, universal management system would ideally be based on an all-encompassing concept, open and adaptive for today's reality and tomorrow's prospect.

[2] German society of knowledge management, http://www.gfwm.de
[3] rebranded as *transversal competence management* – In this paper, the author's original wording is preferred.

Despite of decades of competence definition and classification efforts, no such superordinate concept could be reproduced in recent research. Yet, it evolved in antiquity, from the pre-Socratics via Platon to Aristotle: In Greek, *dynamis* or *dunamis* (later in latin *potentia*) denominates a generic capability as a disposition or potential to cause an effect or induce a change within yourself or to something/someone outside [Ar, Θ.1/1046a9]. This concept encompasses the potential e.g. to explain a concept or answer a question, identify a shape or resolve a formula, drive a bicycle or build a house, moderate a team or manage a company. Aristotle explicitly allows dunamis to inhere in things. Other than most recent definitions, it does not limit itself to characteristics like complex or simple, individual or collective, problem-specific or generic, motivationally dependent or mechanical, and – considering current developments in artificial intelligence and human-robot-interaction – even personal or machine-implemented.

Dispositions are based on representations of the real world in a medium that can bring them to action. Complex representations can be composed of interrelated graph structures of more fine-grained representations. A competence can therefore be located on a continuum between simple and complex structures [Da06, p. 79]. In conclusion, *competence* will refer to *a semantic network of representations, dispositioning its owner to cause an effect or induce a change within, or someone / something without himself.*

2.2 Reference model

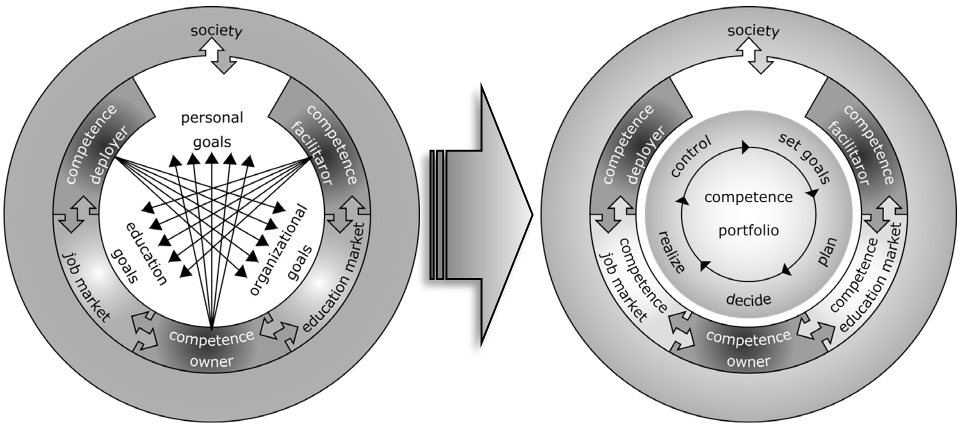

Fig. 1: Conflicting interests in (left) and reference model for (right) competence management (compiled and translated from [DRS16, pp. 8, 16], based on [Da06, pp. 19, 67])

The challenge of integrative competence management, visualized by conflicting interests of three perspectives (Fig. 1, left), is detailed in ten core theses of the SCM [DSR16]:

Digitalization and globalization of work today require – and at the same time facilitate – the effective and flexible operation of competencies and the deployment of the individuals who provide them. Efforts to establish systematic management of competencies stagnate to, much less to be compatible across contexts and institutions to unlock synergies. This may be traced back essentially to the dichotomy between practical context-sensitive implementation on the one side, and cross-context permeability and connectivity throughout all contexts on the other. A solution is likely not to be expected from continuous development within one perspective, but from creative and disruptive integration of all three stakeholder perspectives, making competencies digitally operational and thus transferrable between life phases, regions, and application contexts. A strategic competence management system has to provide permeability and mobility and must aim for interlocking outer and inner lines of educational and economic contexts and organizations. A self-distributed, connectable, and dynamic competence model would be the backbone and the tie of such a system, making competencies available for operationalization across all application contexts, paths of learning, formalization level, languages, and cultures. Rather than rebuilding competences data after each transition to a new context or institution, the new task for human resource management and education is to manage the diversity and transition between these categories. Competencies are neither the asset of a competence deployer (like a company), nor the product of a formation process by a competence facilitator (like a university). Competencies cannot be controlled or even managed from outside, but are personal, intangible, and fluid potential of their owners (e.g. employees or volunteers). Consequently, operation and management of competencies is essentially subject to participation of their owners, motivated by personal and professional goals, transverse to all lines of learning and working contexts and institutions. The competence owner as a key factor seems to have been the blind spot of existing competence management approaches [DRS16, p. 5-7, 12]. An integrative competence management would have to incorporate the owners' reality as a key element of management, at eye level with facilitators on the market of competence-based education and with operators on the market of competence-based occupations [Da06, p. 19-20, 95-98]. This requires institutions of education and economy to open up for a reality where competencies cannot be controlled or formalized top-down, and for integration into a superordinate, universal, but context-sensitive system for modelling and managing competencies between the stakeholder roles of facilitators, owners, and deployers.

Competence facilitators, owners, and deployers are not fixed categories, but roles an actor can adopt:

1. A facilitator can be e.g. an institution providing formal education, a company providing training and job experience, an individual supplying himself with informal practice or research, or a digital education or information service.

2. An owner can be e.g. an employee of companies, a freelancer in self-employment, a volunteer or hobby-enthusiast in public or private life, a learning organization, or an industrial robot, neuronal network or artificial intelligence.

3. A deployer can be e.g. a company with economic goals, a public institution with social goals, a non-profit organization with beneficial goals, an individual

deploying himself for personal goals, or an agent or artificial intelligence.

The full reference model for integrative competence management in Fig. 1 (right) operationalizes all three perspectives, adding a competence portfolio. This interconnecting element makes the conflicting interests accessible for resolution to the management functions “set goals, plan, decide, realize, and control” (based on a more generalized version of Henri Fayol five functions [Fa16, pp. 5-6]) and to occupation and educational market mechanisms explicitly based on competence representations.

2.3 Framework of functions

In a system analysis, a framework of system functions can be derived from the Henri Fayol’s management functions applied to each stakeholder role, and the transverse elements in the reference model (portfolio based on model, markets, society) [Da06, pp. 68-69]. The full analysis and further description of each function, including first approaches to use cases and support tools is specified in [Da06, pp. 69-120]. Chapter 3 addresses approaches to the function *central competence model*.

2.4 Roadmap

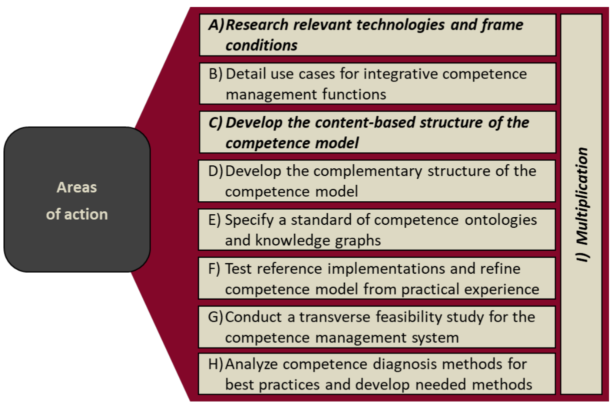

Fig. 2: Research areas for implementation (diagram based on items from [DRS16]).

The SCM concludes its working paper with a call for action in the research areas represented in Fig. 2. The paper on hand addresses aspects of the areas *A*, *C,* and *I*.

3 Requirements

According to own literature research, the nature and functionality of a competence model and the formulation of its instances seem not to have been subject to extensive research so far. The following considerations are compiled from [Da06] and additional contemplations, converging into requirements for competence modelling.

3.1 Types of representation models

The following overview is based on an analysis in [Da06, p. 71-73]. A real element can be represented by natural language description or by a reference. References are abstract, their meaning emerges relative to other references by semantic relationships that can be formulated for machine-readability as in the semantic web, e.g. using the Resource Description Framework (RDF). A set of representations can be structured into a semantic representation model based on different classification types.

Glossaries and hierarchies are often employed forms of classification and frequently employed for competencies models (e.g. European and national qualification frames). But glossaries, as well as hierarchic models like a taxonomy, poly-hierarchy, or thesaurus are inherently inapt for a universal, distributed, context-sensitive representation model as the same inherent problems can be derived:

1. Classification criteria are descriptive with significant potential for inconsistency within itself and with reality (cf. [Fo66], [Wi53]) – In a strict structure, there is no work around to compensate this.

2. They require a controlled set of representations. A centralized control of a global, universal competence hierarchy is unlikely to be operable, whereas the distributed control of many decentral sets will significantly scale up problem 1.

3. The set of representations, as well as criteria for its classification, are a result of context, i.e. the point, direction, and date of view in that the model was created. Application or creation of competence models will have to be either quite generic (und thus, not meaningful) or strictly prescriptive (and thus, not applicable) in order to cross borders of languages, cultures, systems, organizations, communities, or time. Either way, the model cannot adapt to the reality of its users, but users will have to adapt der reality to the model. This jeopardize acceptance of the model.

A graph structure avoids all of these problems by allowing a multitude of relationships in parallel. These relationships can be modelled as semantic triples (subject – predicate – object). Predicates are not limited to hierarchic or synonymy relationships, but can be defined freely in principle (e.g. with instantiation, partitive, or causative relationships). This allows a semantic search that bypasses dead ends by sidestepping via other relationships. A semantic graph structure can follow the multidimensional logic and infer even conclusions that have not been modelled into the graph structure directly. Searching for “can design how – crankshaft – powers – car” might find “can plan how (superordinate) – combustion engine (holonym) – drives (synonym) – front axle (meronym)”. Therefore, a semantic graph structure is the ideal type for a universal, integrative competence model:

It is robust against inconsistencies, or voids, and allows fluid, context-sensitive modelling. Context-specific structures can be interlinked by semantic relationships between them. They are usually modelled as ontologies with added element properties, integrity rules for inconsistency control, and inference rules.

3.2 Proficiency levels in representations

Usually, competencies are described not only by a formulation of the domain of expertise, but also with a proficiency level specification, e.g. from *novice* to *expert*, or in Bloom's taxonomy from *knowing* to *evaluation*. But a hierarchy of representation levels shares the same problems as the representation types in chap. 3.1.: They cannot compensate inconsistencies, have to be controlled centrally, and embody the specific context under which they were created. E.g., in one context, a level has to be completed to reach another – which may be seen differently in other contexts. Also, even after detailed description, a level is still highly interpretable. Instead, competencies should be broken down into a set of more fine-grained representations that semantically explain the difference between e.g. *novice* or *expert*. Those competencies can be grouped to more complex competencies, resembling a specific level of proficiency or expertise. This allows to access the complex representation as a set, as individual fine-grained competencies below, or as a different group that is linked to competencies below.

3.3 Modelling the "disposition to <x>"

Semantic structures are often implemented as ontologies. Usually, ontologies model physical or metaphysical aspects of the world with triples. E.g., a typical semantic triple would be "[recursive function] – [sorts] – [data]". To model a competence, a fourth element would be required to indicate disposition (e.g. verbalize, plan, create, modify, analyze, etc.), e.g. "[can describe how] – [recursive function] – (to) [sort] – [data]"). Variants for implementation of such competence quadruples could be:

1. Adding a disposition attribute to a semantic triple representing the effect. Each type of competence would require a new, standardized attribute value that would have to be an integral part of the universal competence model and thus difficult to change without side-effects to existing data.

2. Linking a semantic disposition object to an auxiliary semantic triple object, much like a sequence object of the Resource Description Framework (RDF). Each type of competence would require a new predicate instance. Predicates would not be part of the model logic, but modelled data in any ontology, accessible for semantic search and inference.

3. Similar to the previous point, the whole ontology by itself could be modified to consist of semantic quadruples rather than semantic triples. But for semantic search, it would be good to allow semantic statements without a disposition.

The inflexibility of a disposition attribute should be avoided. Further research is required to evaluate variants 2 und 3.

4 Guidelines

For the functional requirements[4], the following guidelines can be derived:

- Everything within the definition in chap. 2.1 can be modelled as a competence.
- A competence is modelled as a semantic representation, consisting of a specific quadruple set of a subject, a relationship predicate, an object, and a disposition.
- Taxonomies, categories, levels, and other assortative information must not be coded into the model itself, but as relationships into the semantic network data.
- Representations are hosted in distributed context-specific ontologies, so each actor in each domain can create, publish, and maintain his own ontology.
- Ontologies can be interlinked with relationships for transverse semantic search.
- Ontology data can shared, standardized, or outsourced to a desired degree as meta- or inter-ontology, e.g. for standardization or economic reasons (e.g. for coinciding competencies, for language translation, or for small organizations or freelancers without resources to model competencies).
- Competence owners can link themselves (or be linked) to competencies of any published ontology. The set of such links is their competence portfolio.

5 Outlook

The guidelines in this paper were derived from general considerations and requirements, as a first step to specify the structure a distributed representation model for a universal, integrative competence management system. Further research is required on how to implement and operate these concepts. Even with distributed context ontologies, the creation and maintenance effort for such a system is considerable. Other approaches can be considered as a parallel system like the automated generation of knowledge graphs that would be much faster, but less reliable, and elements of the graphs can be persisted by incorporating them into a controlled ontology. Overall, test competence data has to be gathered and analyzed from different contexts to refine the structure.

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[4] For non-functional requirements, see “frame conditions” in [Da06, p. 62-67] and “interface for regulation” [Da06, p. 98], and “attributive structure” in the SCM roadmap [DRS16, p. 23]

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