Agility and Semantic Structures to Scaffold Modern Academic Education

Supporting the Digital Transformation in Higher Education Institutions

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***Abstract*—Higher Education Institutions (HEI) are faced with a number of challenges in these days: The sector is becoming more competitive and the education profile need to become more dynamic: the amount if knowledge is ever increasing and – especially in the technical subjects – knowledge is out-dating fast and new knowledge is emerging. As a consequence, the education system in HEI needs to become more agile and more modular. The current situation is reflected upon the VUCA paradigm and some solutions will be proposed to address those challenges. As education programs are carefully crafted in a manual but unstructured way, this contribution suggests the support by a scaffolding of semantic structures that helps to create connected, modular education items that can be used as Pre-built information spaces for learning environments. The main contribution of this paper is a concept of a simple and universal model to structure learning outcomes in a more structured form in order to create a foundation for a better understanding for human users and machines alike.**

Keywords—Agile Methods; Semantic Web; HEI; VUCA; Digital Transformation.

I. INTRODUCTION

The digital transformation of our economies and societies is also a challenge for the sector of Higher Education Institutions (HEI). Education programs become more digital components; this process had been accelerated by the COVID pandemic but is probably also as aspect that is bound to remain a substantial part of the sector. Moreover, the sector is becoming more competitive – at least in the DACH region (Germany [D], Austria [A], Switzerland [CH]) – and HEI have to deal with new and global competitors, also coming from the private sector. At the same time, knowledge to be transferred to students becomes more in terms of volume and complexity and is outdated fast due to technology developments. Lifelong learning as a concept that deals with constant learning is also slowly becoming a reality with the direct consequence that part-time programs become more popular for secondary studies (e.g., in Masters programs). This seems to be especially important and demanding in all the engineering sciences, with the Computer Science and its related disciplines and cross-cutting subjects as probably one of the fastest evolving subjects.

As a result, the education programs offered by HEI have to address these challenges by becoming more modular and open in order to be combined with each other and to be innovated faster. The demanded agility is currently hard to achieve an education programs are designed and accredited in a process that takes years instead of months and the execution phase usually starts yearly and has a duration of two to three years for one cycle. Thus, innovation in education programs is at the scale of 5-10 years.

The specification of an education process is a careful and manual process and is usually being carried out with extensive text-based documentation. Qualification profiles, competencies and curriculum content is being described in an unstructured way, which makes it hard to validate and aggregate the content from the program level to the lecture level and back. A better structural and semantically oriented support could be useful as a scaffolding support. This could be helpful in all phases of the process (during design, while executing and finally when assessing student results) and Semantic Web technologies are a promising way to support such a scaffolding in terms of providing additional information (meta-data) to trigger and to support directed self-learning services. With that respect the textual specification documents evolve into knowledge-based user interface for students and lecturers alike that can be used for knowledge intensive task in the learning phase (students deciding which module to study next) and the teaching phase (lecturers designing content in a more outcome-oriented way according to the competences that ought to be taught).

While a semantic structuring supports the consistency of programs with respect to learning outcomes and competences it also contributes towards the agility of the programs by exposing interfaces in terms of learning outcomes that could connect to other education programs within an HEI or outside of an HEI. And finally, agility might also be of interest for the student who is increasingly involved in Problem-Based Learning scenarios (PBL) in which knowledge is being created and used, based on the tasks given.

The rest of the paper is structured as follows: In Section II the current situation of HEI is analyzed with respect to the VUCA paradigm. VUCA is the abbreviation for a number of properties of certain environments: V – Volatility, U – Uncertainty, C – Complexity and A – Ambiguity [1][2]. A number of high-level suggestions for addressing those challenges is made, again employing the VUCA solution paradigm with an interpretation to the domain of HEI [3][4]. After that the concept of hierarchic competence matrices is introduced in section III with the focus on connected application throughout the different levels of an education program. The support for the creation and execution in terms of semantic scaffolding using Semantic specification

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documents is introduced in Section IV. The paper concludes in the final Section V with an outlook at future research activities.

II. HIGHER EDUCATION IN A VUCA-WORLD

Higher Education is process that is spanning several years in each iteration and prepares students for their professional life. Consequently, long innovation cycles in their curricula are the result which does not suit well in a dynamic and fast changing environment [5]. The concept of a VUCA-world is commonly used to describe environments with a large degree of change and the required frequent adaptation to a changing or new environment. The current changes in the digital transformation of society and economy are also having an impact on the HEI and thus creating a VUCA-environment for education programs that HEIs need to address.

In the following, the author will analyze how the different aspects of VUCA can be addressed in the execution level and the management level of education programs in HEI. Both levels are quite interconnected as the execution level is dependent on a certain flexibility of the lecturing in a certain while still maintaining the original learning goals of the curriculum. Furthermore, it is important that the novel and agile approaches still exhibit a wide range of scalability from small groups to large groups and from presence teaching to distant teaching as well. At management level, it becomes more important, that individual lectures are dynamically orchestrated into a curriculum, that might be more individualized that structures education programs in the past. At the same time, individualization and the interfacing to prior knowledge and post-graduate education becomes more important.

Now each of the components of a VUCA world in the context of HEI are dealt with in more detail:

(V) – Volatility in the context of HEI can be interpreted in terms of changing topics that are concerned relevant and/or interesting by the external stakeholders (students, companies), but also in terms of volatile group sizes due to those trends. As programs are designed and funded in the long run, adaptation to those volatile aspects is becoming a challenge.

(U) – Uncertainty in HEI can be interpreted as the fact that the education system is currently changing by external drivers like the digital transformation, the lasting effects of the COVID pandemic and changing expectations of future generation of students. As topics and education profiles are changing and new job profiles are emerging or did not even exist yet, education planning for the long run is difficult – development and financing phased is not designed for such an uncertain environment and thus has constantly to adapt (which requires resources to employ the change). Uncertainty in the economy also leads to an increased amount of part time profiles of working students. This leads to a demand of lifelong learning and lifelong education, that both sides (students and HEI) are not yet ready for.

(C) – Complexity is a common pattern in fast evolving subjects as most engineering programs and can be interpreted in two ways: an increasing complexity of the fields in terms of subjects becoming broader as well as subjects having a deeper level of knowledge that is needed to master it. This is leading to the observation, that educating students becomes a challenge, as the time for education remains the same (2-3 yrs. in BA/MA) and could not be extended. Part-time students add to the difficulty of the problem as their time budgets are even more limited. For lecturers it becomes more relevant to select the right content and to moderate the learning process – in that sense they are becoming guides and curators for the knowledge that is transferred to the students. In order to keep a close contact to the practical application they need to work with real-world examples but also need to convey more general pattern that are relevant to their field.

(A) – Ambiguity in the context of HEI can be interpreted in the fast-evolving knowledge domain in many subjects. Concepts that attain a lot of general interest like Digital Transformation, Artificial Intelligence and the Cloud technologies, for example have multiple meanings and require different levels of knowledge to become actionable. Understanding those concepts and applying them in real-life scenarios if often the requirement for engineering students but often to conflict with the expectation from the general public what technology could do or could not do.

Different stakeholder groups (e.g., business, technology, society) have a quite different understanding and expectations. For the education this leads to the challenge of educating students in an informed and adequate way without the danger of getting too much in the complexity trap.

The solution space in a VUCA-world used the same letters with a different meaning and in the following an interpretation in the context of HEI could is proposed:

(V) – vision is adhering to the fact that an operational guidance is needed to navigate through changing topics and still retain a USP or core competence for the HEI. Here, the situation is similar to those of companies, but might be interpreted in a different way, e.g., it could be value driven in the sense that it is important to develop applicable knowledge, or to employ a guiding attitude to the education of the students. Such a vision needs to be employed in practice and is therefore more of a cultural value that is developed by employing a vision.

(U) – understanding could be seen as an active and ongoing reflection process on the requirements of the application domain (business & society) but also the expectations and requirements of the current and next generations of students to act accordingly. More than in the past this is also an interplay and a communication of values between different generations: lecturers ("older generations") and students ("newer generations"). That always had been the case, but in a VUCA world this process is being accelerated and in the sense of a dialogue more important.

(C) – clarity in a VUCA world is an important role that HEI can play: by building on existing knowledge and by employing scientific methods and an objective view of the world HEI can help students to provide orientation in a complex and changing world and convey them important toolsets to navigate in that world at topics that they are faced later in their life.

(A) – agility becomes more important on the strategic level (for the development of programs) and the operational level

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(the execution of programs). While the former is required to develop and adapt programs faster the second aspect addresses the aspect on how the execution of a program is tailored to the specified group of students in front of the lecturer and even towards the individual. This leads to the fact that learning analytics becomes more important and that digitization can be used to provide additional or alternative learning paths.

III. HIERARCHICAL SKILL MATRICES FOR SCAFFOLDING COMPETENCES IN EDUCATION PROGRAMS

In order to address the challenges for education programs derived by the VUCA analysis a more structured approach on designing and executing education programs is needed. Currently those programs are specified mostly using informal descriptions a non-standardized structure for the curricula. Especially for the core concepts of competencies that are the result of the learning outcomes of the individual lectures of a program no specific support structure is being provided. This approach has two important drawbacks: (1) The problem of *consistency* among the different abstraction layers of a program and the different interpretation at design time and execution time. (2) a limited support for *modularity*, as there are no clearly defined interfaces among the different components. Modules in current programs are designed around its content but do not clearly expose the competences in a way that could act as an ‘interface’ for other modules. Making competences more visible and structurally comparable might help to create more consistent programs that provides modules, which can be reused more easily.

In order to address those issues, the concept of hierarchical Competence Matrices is being created. The concept roots in the observation that in modern Curriculum Vitae (CV) competences are often presented in a more visual form of scales, as illustrated in Figure 1 below. Although being not exactly precise the representation delivers an immediate profile of the competencies of a person, albeit on a very general scale.

Figure 1. Template of a skills & expertise in CVs [6]

A second observation is taken from the domain of foreign language competences. Here, the Common European Framework of Reference for Languages (CEFR) established an accepted framework for language proficiency that encodes a rather complex subject in just six reference levels (A1, A2, B1, B2, C1, C2).

Both models are simple to understand, and despite their generality widely used. This contribution builds on those ideas and extends it towards a hierarchical relation among different competence or skill matrices. A *Competence Matrix (CM)* is a set of competences that are identified with a brief description and are assigned an attribution according to a skill or competence level that could use Bloom’s taxonomy [7] or a similar model [8][9]. Such a taxonomy defines a number of levels at which a competence could be classified, such as remember, understand, apply, analyze evaluate and create.

The central idea of *hierarchical concept matrices (HSM)* is the connection of different but related CMs to create a relation along different levels of an education program (general to specific) and from different parts of the life cycle of such a program (from design to execution)

The following Figure 2 illustrates a number of HSM along three levels

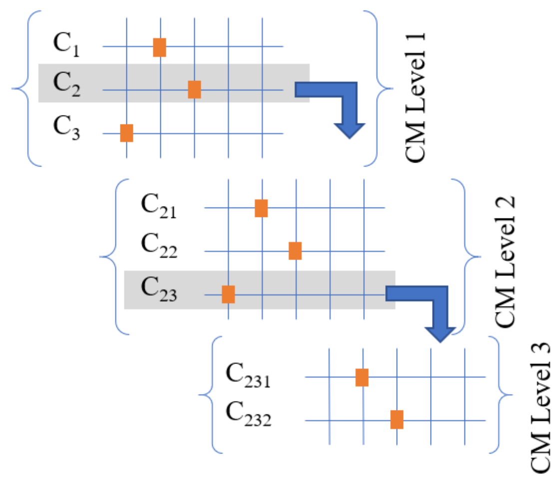

Figure 2. Illustration of HSM along three levels that are interconnected, e.g., on program level (1), at syllabus level (2) and at the level of a lecture being held (3). Scale and structure of the HSM remain the same and a direct connection of $C_1 \rightarrow \{C_{21}, C_{22}, C_{23} \cong \{C_{231}\, C_{232}\}\}$ can be derived.

The HSM could be connected in a strict hierarchic fashion, leading to a taxonomy of competences that are being constructed from more general (at program level) to more specific (at the level of instruction). In practice it might be the case that a competence is being provided or needed by different CMs at a deeper level, which leads to a graph like structure as cycles might be a part of the hierarchical structure. Another way of connecting the CMs would be the interpretation as a function that maps a set of competences (at a lower level) to a single competence (at a higher level), changing its attribution value *attr*: f: $\{C_1, C_2, C_{3, \ldots}\} \rightarrow attr(C)$.

The most important feature is the connectivity of the CMs that resembles the HSM, because it constitutes a connected competence model for all phases of an education program of an HEI that can be used for students and lecturers alike an explanation model to provide guidance and structuring. In that sense it really provides a scaffolding for designing and executing education at HEI. Moreover, it lays the foundation for a validation of a competence model by enabling to check for missing links or competences that are taught but never used, for example. This could help to improve the education modules in an iterative way and to ensure quality with respect to didactic design and content.

IV. A Prebuild Information space for learning

The concept of HCM contribute to the notion of Pre-built Learning Information Spaces for Learning Environments [10] that are aiming at supporting students in a VUCA world to address the needs of the future in Higher Education efficiently. It provides the component to connect different specifications documents together that are otherwise unconnected, such as syllabi of different lectures or the syllabus and the learning content in a learning management system (LMS).

HCM could be embedded in specification documents that contain semantic encoding, so called *Semantic Specification Documents (SSD)* – for a detailed description, see [10]. In essence, an SSD is a document that contains metadata in a semantic encoding that models textual descriptions in a machine-readable way; see Figure 3 below.

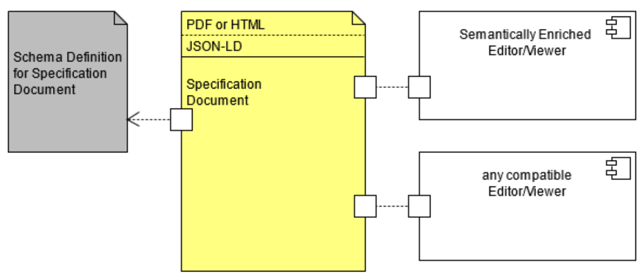

Figure 3. Semantically enriched documents as containers for HCM [10]

The important aspect of such an SSD is the fact that the semantic annotation is directly attached to the document itself and is available to creators and viewers of the document without the need for an external IT-system. It is self-contained. In order to retrieve the information that is dispersed over different SSDs, an aggregation step is needed. Such an aggregation would collect and analyze all the documents of an education program and collect the extracted semantic information in a specific database (called a triple store). Queries would be run against this store in order to satisfy an information demand; see Figure 4 below.

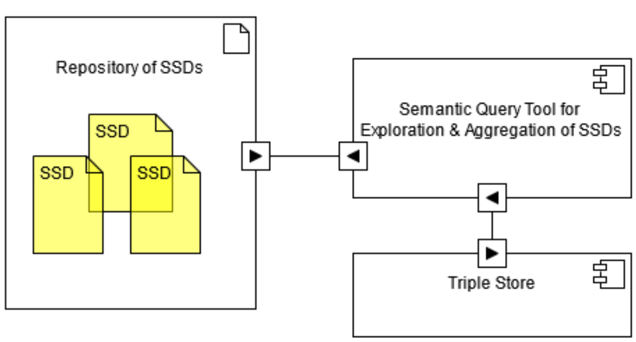

Figure 4. Aggregating of SSDs in a repository of documents to provide querying against a triple store [10]

The combination of HCM as a conceptual model with SSDs as a distributed and document centric representation model helps to work towards a concept of semantically defined learning specifications that can be used to describe the benefits of explicit formal descriptions to structure the curricular content in HEI to build semantically and agile learning environments (“SALE”) in order to support the teaching and learning process at the level of meaningful learning objectives. It also provides interfaces to prior knowledge and post-graduate education, which will become more important in a world of true lifelong learning as it is required in a VUCA world.

V. Conclusion

This contribution analyzed the current situation of the HEI with the help of the VUCA paradigm and presented how a more structured, modular and agile approach is needed to address the changes that are ahead of the sector in the process of digital transformation. In order to provide a more structured approach, it is important to involve all stakeholders in the process with an easy to understand and easy to use model to express competences at different levels. Hierarchical Competence Matrices are introduced for that respect and the concept of semantic specification documents can be used to implement this tool set. The main contribution of HCM to VUCA is the increased focus on connected and explicit learning outcome that are specified in a uniform way. This improves clarity (“C”) and helps to students and lecturers to understand (“U”) the intention (or vision (“V”) of the education program better. Due to the exposed structure it also helps to make missing aspects or changing topics more visible and provide intervention points for improving programs in a an agile (“A”) way, helping designers of course programs. For the student, however, the structure can be used to provide agile teaching support by considering his or her progress using learning analytics, derived from the interaction with the LMS.

Based on this conceptual work the next phases of this research are going to provide an implementation and codification of the hierarchical competence matrices from the bottom up starting with modeling of a single lecture to a whole program and then potentially to the programs of a whole faculty. Evaluation of those implementation both in terms of understanding and scaffolding support will be the next steps in the research that is being carried out of the author who is both in the lecturer and the researcher role, thus being able to interpret findings from multiple perspective together with colleagues and students.

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