Knowledge Management Framework to Enable Effective Curriculum Development and Self-determined Learning

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Abstract
Educational organizations – whether they be schools, colleges, universities, or statutory institutions – play a cardinal role in the development of knowledge, skills and competences, first-hand through the development of relevant and effective curricula. At the same time, this must ideally also enable academic freedom and allow the learner to practice self-determined learning, which has been shown to yield much higher motivation and cognitive performance over traditional methods. However, due to inter- and intra-organizational knowledge fragmentation, there has been great challenges to assess the relevance of curricula by identifying knowledge gaps and the need for curriculum adjustments, for instance, due to course outcomes that may not (or no longer) serve a purpose. This challenge is amplified when the intention is to further ensure a degree of autonomy and personalized learning to encourage due ownership of the learning path by the learner. In this paper we describe and discuss a prototype tool, called "Software for Target Orientated Personal Syllabus" (STOPS), developed at Aalto University to address these fundamental issues in engineering education. We further associate the concepts and features of STOPS with broader theoretical framework of knowledge management (KM). KM has been a prominent study field for organizational value optimization in a variety of commercial, engineering and scientific sectors, by curbing knowledge fragmentation. KM brings together three core organizational resources – people, processes, and technologies – to enable the organization to create, use and share knowledge more effectively. In recent years KM philosophies and instruments have begun to propagate into the education field. We discuss how STOPS, an apparent curriculum-planning tool, can serve as a tangible manifestation of abstract KM principles, in particular, for engineering and science education. Lastly, we briefly allude to the rapidly changing job markets amid the advent of mass digitization, and how the fundamental impacts on the dynamics of education can be better managed using data mining and machine learning techniques built upon the existing STOPS concepts

1. Introduction
Educators today are tasked with cultivating learners who have the capability to effectively and creatively apply skills and competences to new situations in an ever-changing work environment [1]. Educational institutions may longer be fully capable of preparing learners for thriving in the workplace, and a more self-determined approach is needed, where educators teach learners how to teach themselves. The well-established self-determination theory [2] underpins the relationships between intrinsic motivation, mental well-being, self-regulation and autonomy. In principle, self-determined learning applies a holistic approach to developing learner capabilities, with learning as a proactive process, and learners serving as "the major agent in their own learning, which occurs as a result of personal experiences" [3]. Understandably, self-determined learning poses an enabler for the effective and continuous acquisition of relevant lifelong knowledge, skills and competences (KSC) required in the changing times.
The "Software for Target-Oriented Personalized Syllabus" (STOPS) was developed [4] to assist students and/or teachers to build up goal-specific learning paths, and assess the curricula on the basis of learning outcomes. STOPS was developed as a curriculum planning tool, but its principles are being further extended as learning augmentation through improvement of self-determined KSC development – hence attributing STOPS as a Knowledge Management (KM) tool. There is no single accepted definition of KM, however, considered broadly KM in education can be thought of as a framework of approaches that enables people within an organization to develop a set of practices to collect information and share what they know, leading to action that improves services and outcomes [5].

A KM theoretical framework is needed to underpin and broaden the relevance of STOPS and curriculum planning in general. The aim of this short paper is to describe the STOPS functionalities and promote its epistemological relevance beyond education, by virtue of our current efforts in further processing the STOPS data. A theoretical framework based on KM is discussed, to which further computational developments can be underpinned. This also lends itself to demonstrate the isomorphic nature of different, seemingly lesser related fields and the importance of holistic understanding to deepen the rational relevance of learning/education instruments and technologies, in particular, their extended use as so-called KM systems. The research is yet in its infancy and warrants a long path of development, as the complex interplay between technology, processes and people in different contexts becomes better understood.

2. Software for Target-Orientated Personalized Syllabus - STOPS

STOPS is a multi-purpose tool for developing a university syllabus and creating personal study plans for students. The original intention was for core curriculum analysis (CCA), however CCA was soon discovered not suitable for categorizing learning outcomes within a single course as different KSCs are important for different students depending on their specialization preferences. Consequently, the idea of a personalized curriculum was adopted. The STOPS therefore serves two purposes: it allows teaching staff to design a curriculum model and students to construct personalized study plans [4].

The curriculum model consists essentially of *courses*, *outcomes* with respect to each course, and *prerequisite dependencies* that connect the outcomes. These are inputted by teachers in charge of the respective courses through an interface allowing previously entered *outcomes* of other *courses* to be selected as *prerequisites*. This curriculum model results in a graph of learning outcomes that depicts the structure of how KSCs are covered and propagated through the curriculum. Figure 1 shows the primary visualization function of STOPS. User has clicked the "Student can analyse the stability of a beam" *outcome* and the outcomes connected to it have been highlighted. Prerequisite courses are to the left. Mandatory prerequisites are marked with solid lines and supporting ones with dashed lines. This allows students to see where the topics covered in each course (outcomes) are needed in subsequent courses and how they contribute to the end goals of the student. On the other hand, curriculum developers can use the visualization to identify KSC gaps and/or cognitive overload over the full curriculum structure.

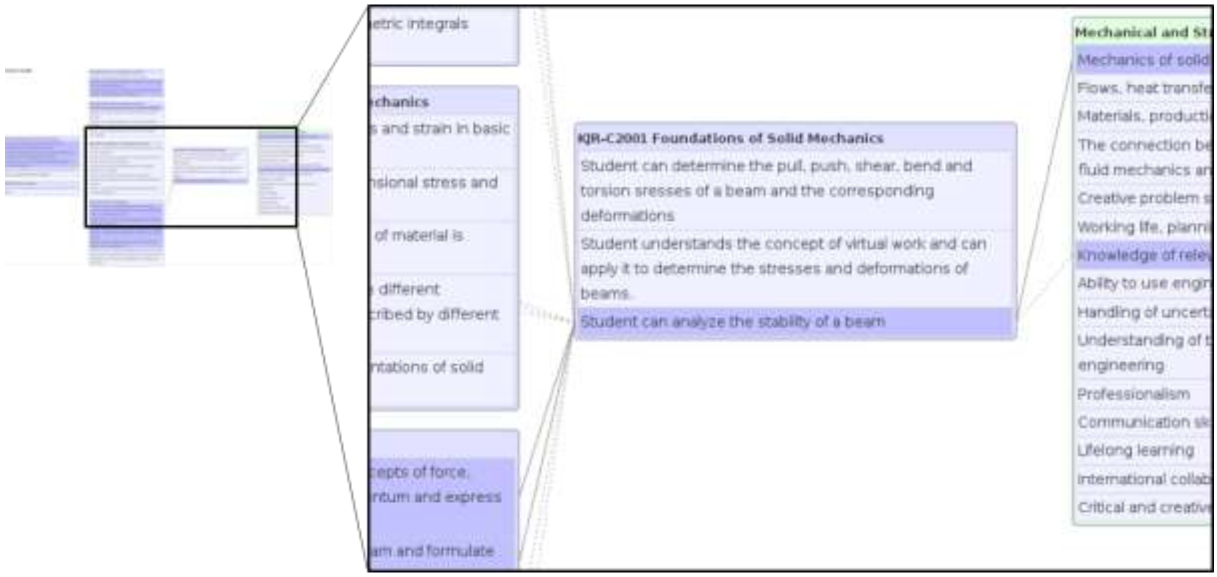

Figure 1: Interactive graph visualization for the Foundations of Solid Mechanics course within the Mechanical and Structural Engineering curriculum.

STOPS was used for the new bachelor's programme of the School of Engineering at Aalto University. The system exhibits novelty by capturing course outcome-level prerequisite relationships, rather than merely between courses as in traditional curriculum mapping methods. This enables learning paths based on the links between course outcomes (hence KSCs) rather than courses, giving more informative description of the curriculum structure.

3. The knowledge management perspective

Today it is widely accepted that knowledge, in all its complicated and dynamic forms, remain any organization's most significant resource in creating value. This is especially true in today's rapidly changing organizational ecosystems, where the element of uncertainty gives knowledge a prime importance [6]. Different authors have presented different definitions of Knowledge Management (KM). A combined generic definition for KM can be briefly given [7]–[9]: "The process associated with the creation of new knowledge, the sharing and transfer of new and existing knowledge, the capture, storage, exploitation and measurement of the impact of knowledge, in such a way that it benefits the unit of adoption". It is important to distinguish between data, information, knowledge and wisdom in the knowledge management framework. As data and information are processed and interpreted, and become invested with meaning through analytical thought processes, they increase in utility and value. Figure 2 describes the knowledge hierarchy.

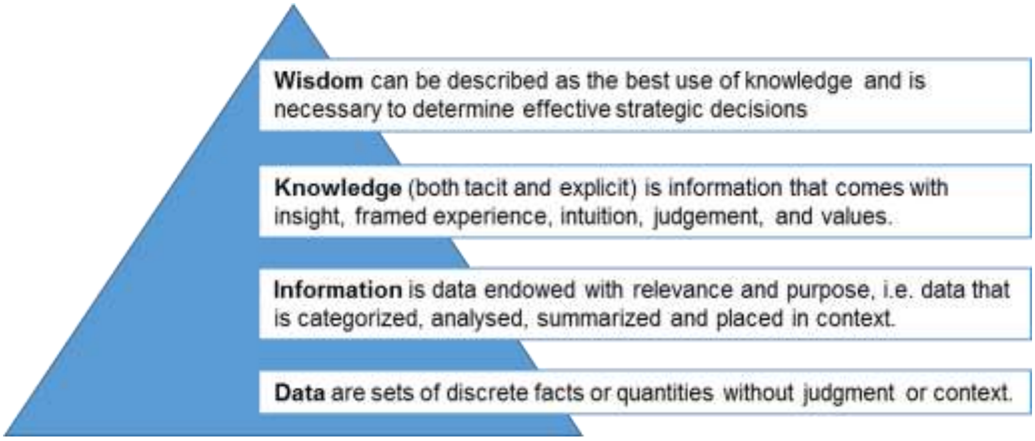

Figure 2: The knowledge hierarchy. Adapted from source [10].

In addition to the knowledge hierarchy, seminal KM literature broadly differentiates knowledge into *tacit* and *explicit* forms [11], [12]. The Knowledge Creation Cycle [12], also known as the "SECI model", emphasizes the importance of interactions between tacit (human, non-codified, behavioural) and explicit knowledge (documented, codified, functional) in organizational learning. SECI refers to the four processes of the cycle namely: Socialization, Externalization, Combination and Internalization. Today, it remains the cornerstone of knowledge creation theory [6], [13]. Figure 3 combines the SECI theoretical framework with the STOPS processes.

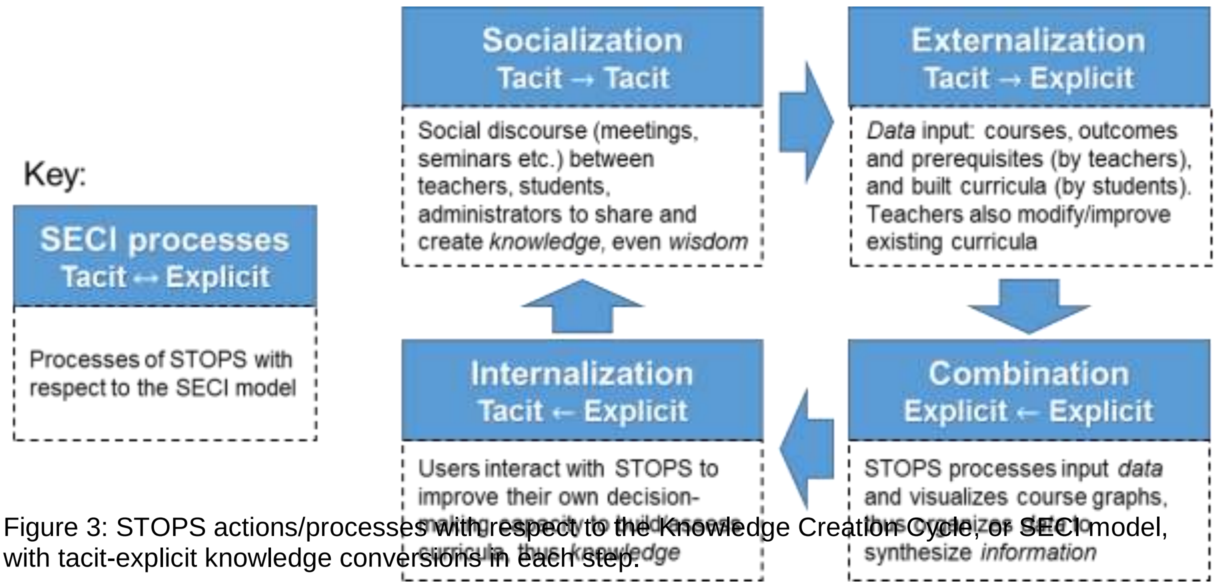

Figure 3: STOPS actions/processes with respect to the Knowledge Creation Cycle, or SECI model, with tacit-explicit knowledge conversions in each step.

The SECI model involves people, processes and technology and highlights the importance for synergy between these aspects for the successful implementation of KM principles. This interpretation allows for curriculum planning challenges and STOPS to be explained from a KM perspective, where improved capturing of data can be aggregated and organized to be shared as information amongst teachers and students to improve their capabilities in selecting a learning path, while their tacit knowledge develops dynamically through iterative cycles of interaction with STOPS system and one another.

4. Discussions and ongoing development

General educational software and process automation emphasize the “explicitly-inclined” Combination and Externalization aspects of the SECI model, whilst “tacitly-inclined” Internalization and Socialization aspects are separately underpinned by perspectives such as the social constructs of knowledge, learning theories, and psycho-behavioural studies. These views do not converge very tidily on the essence of KM and how it should be qualified. Traditional information technology (IT) has been weak in handling the tacit aspects. Indeed, STOPS user studies indicate that more developments are warranted on the social/people aspects and wider adoption [4].

In the meantime for STOPS, at least more data can be captured in the Externalization process. Likewise the Combination process can be extended in analytical functionalities to synthesize meaningful “lessons” from data – e.g. most/least widely chosen learning paths and possible reasons; specific student feedback on different courses; recurring issues during curriculum building etc. Furthermore, students’ performances or other existing measurable indicators of learning can be tracked, aggregated and further analysed in association with STOPS data. IT may not necessarily yield deterministic answers, but at least offers students/teachers deeper insight when making decisions to solve respective problems, thus posing a large-scale, yet personalized, cognitive aid through continuous iterations of the KM process.

Concepts such as knowledge permeability/transferability/compatibility are common ideologies of the European Commission, which emphasizes the necessity for knowledge partnerships and global alliances. However, given the plethora of knowledge, skills and competence (KSC) standards, taxonomies, qualification frameworks etc. it remains difficult to achieve consistent epistemological reconciliation and identify permeable/transferable KSCs across frameworks. Such tasks are traditionally laborious, requiring substantial human cognitive reasoning, since the hermeneutical, interpretive approaches still dominate in such work. This discourages explicit definitions of (and linkages between) specific KSC descriptions across different frameworks. Though understandably so (knowledge being inherently fuzzy and subjective), this is also a great barrier to adoption of different IT tools. Nevertheless, we are investigating deeper into this fundamental challenge through the use of advanced stochastic data analysis.

5. Conclusion

Today’s rapidly-changing knowledge economies require educational institutions to respond quickly to the fluctuating demands of knowledge, skills and competences (KSCs). Self-determined learning allows for personalized lifelong learning, be it for students or professionals to be at the core of their own goal-specific learning/career guidance. To facilitate this, a semi-automated recommender system needs to be provided, with the reach of broad relevant data and information in order to assist the user in making the best decisions. The STOPS, as a mere curriculum planning system, was the first step towards a full-fledged solution for self-determined path guidance. Further attributing the STOPS to KM principles allows for existing STOPS functionalities to be endowed with deeper theoretical rationale for leveraging curriculum design with broader considerations. In addition, the KM theoretical framework provides a foundation for the development of derivative systems. Although KM is complex and thus understood differently in different contexts, it remains fundamentally an iterative process that strives for continuous improvement, giving the human the best decision-making capacity by the synergy of people, processes and technology, and embodying both tacit and explicit dimensions of knowledge. Although tacit (human/social) aspects are typically poorly handled by IT systems, technology can nonetheless assist the Internalization and Socialization processes. The advent of the digitization megatrend in recent decades has spurred remarkable IT developments and changed to varying extents the traditional sense of tacit and explicit knowledge. There are countless examples where tasks, previously enabled through human reasoning, are currently fulfilled by automated products or processes. Therefore the importance of investigating KM under the light of data processing and machine learning is self-evident and ever so pertinent.

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