SHARING KNOWLEDGE ENGINEERING FOR DIGITAL HUMANITIES

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Abstract. In this paper, we present a first attempt to integrate Collaboration Engineering with Lean Six Sigma principles applied to Project-based Learning.
On the one hand, collaboration is a social and interactive process, where participants join efforts toward a shared common goal. On the other hand, Lean Six Sigma is a unique methodology integrating a shared language, statistical measuring and effective process management techniques, using Axiomatic Design to structure and optimize the training model needed for Project-based Learning. Speaking a common language allows to improve interfunctional problems where people with different competences are involved.
Drawing on Collaboration Engineering and the Lean Six Sigma logical model, the paper explores the use of a collaboration ontology to capture and share knowledge about collaboration work and processes.

Keywords: Knowledge Engineering, Collaboration Engineering, Lean Six Sigma, Project-based Learning, Axiomatic Design

1 Literature review and research scope

1.1 Capturing Semantics in Ontologies

Ontology as a tool for knowledge representation has been studied and applied in the context of many fields such as within information science, knowledge engineering, artificial intelligence, or digital libraries. Gruber’s (1993) work is still considered fundamental in the field of ontology engineering and design, and ontologies for knowledge sharing. Various introductory literature to ontology learning addresses specific techniques according to the type of information sources used to extract knowledge (Roussey et al. 2015).

Knowledge engineering approaches have mostly focused on description logics and formal foundations of ontology design (Gavrilova et al. 2015). However, as Gavrilova et al. 2015 pointed out, “informal approaches based on human-centered ontology design processes” have been mostly neglected, despite previous attempts as discussed in, for example, Kotis et al. (2006) or Iqbal et al. (2013). In the context of the proposed project, such human-centred and collaborative activities will play an important part in the cognitive design of ontology facets. The proposed project is likely to contribute to the further investigation of human-centered ontology design methodologies.

Ontologies supporting Information Retrieval based on texts is well understood. Research in this area comprises mainly semantic search models (Fernández et al. 2011) and user studies (Katifori et al. 2015), however, mainly in technical and natural scientific domains, whereas research addresses the humanities with considerably less attention.

More recent research projects make use of fuzzy concepts in order to reduce what has been called the semantic gap (Nagarajan et al. 2015; Remi et al. 2015), described by Hein (2010) as "the difference in meaning between constructs formed within different representation systems". Zarka et al. (2015) propose a framework and workflow consisting of the two steps of constructing a fuzzy ontology through analyzing learning dataset and guiding the annotation process through a reasoning engine.

An image can be expressed in text by annotating it in relation to the object around it. Research focuses on text based image retrieval, content based image retrieval, and ontology based image retrieval techniques (Halaschek-Wiener et al. 2005; Llorente 2008; Datta et al. 2008). Lew et al. (2006) name the major challenges for the content-based method, notably inconsistency as the major issue in using folksonomies. As another approach, the research area of Semantic Image Interpretation looks at the ontological description of images. Two prominent approaches follow logic-based techniques and recently also neural networks-based approaches, including promising deep-learning methods (LeCun et al. 2015).

Lastly, ontology alignment and matching techniques, as recently reviewed by Otero-Cerdeira et al. (2014), will also play an important part in the proposed project, since multiple ontologies can be expected to be of relevance to the description of entities in textbooks as well as for the representation of appropriate ontology facets. Furthermore, as Khodaskar et al. (2015) discussed, ontology alignment promises to improve image retrieval by means of more than one integrated ontology.

1.2 Research Methodology for Ontology Engineering

Ontology engineering aims at building a formal representation of domain knowledge (concepts in a domain) and creating a common understanding of the structure of information in the domain (relations be-tween the concepts) among people or software agents (Predoiu & Zhdanova, 2007; Studer, Benjamins, & Fensel, 1998; Gruber, 1995). Today, several methods and methodologies for developing ontologies exist (Corcho, Fernández-López, & Gómez- Pérez, 2003). Uschold and Gruninger (Uschold & Gruninger, 1996) present a methodology for ontology engineering. We adopted these methodologies for ontology building (Grüninger & Fox, 1995; Pinto & Martins, 2004) for our collaboration engineering process (Knoll et al. 2012). We used this approach to develop our collaboration engineering ontology and will adapt it with agile methods for the purpose of this proposal. The purpose of the collaboration ontology is to describe collaboration from an external point of view and adapt it to the different views (in our case the different disciplines).

1.3 Collaboration Engineering

Collaboration is very important in many aspects of our lives. When we work together, we can reach goals faster, yield better results and in-spire each other during our collaboration activities. The synergy effects can boost all kinds of endeavors tremendously. However, there are also collaboration efforts that do not work well. Thus, it is very important to be able to assist, analyse and support collaboration with technological means. With this proposal, we want to explore this methodology in a real world example and give best practices on how we suggest to utilize ontologies for the given collaboration process in digital humanities.

In previous work (Knoll et al. 2012) we analysed semantic approaches for Collaboration Engineering. We presented a new ontology-based approach, where each concept of the ontology corresponds to a specific collaboration step or a resource, to collect, manage and share collaboration knowledge. We discussed the utility of the proposed ontology in the context of a real-world example where we explain how collaboration can be modelled and applied using our ontology to improve the collaboration process. Furthermore, we discussed how well-known ontologies, such as FOAF, can be linked to our ontology and extend it. While the focus of the work was on semantic Collaboration Engineering, we additionally presented methods of reasoning and machine learning to derive new knowledge about the collaboration process as a further research direction.

1.4 Project-based Learning Methods

This section introduces an example of Collaboration Engineering applied to project-based learning, using Lean Six Sigma principles, and, specifically, Axiomatic Design (Suh, 1990), as debated by the authors in (Arcidiacono et al. 2016).

Lean Six Sigma (LSS) is a strategy involving the entire organization in the challenge to reduce defects to achieve Customer Satisfaction. Therefore, LSS isolates main criticalities of the whole process in sub-phases, thus dividing the overall problem into smaller areas to improve process knowledge and to solve it with surgical precise actions (Arcidiacono, Costantino, & Yang, 2016).

Conventionally, the onset of Project-based Learning (PBL) dates back about one hundred years ago to the work of the educator and philosopher John Dewey, who first implemented the notions of learn by doing into a constructivist pedagogical approach to education. Project-based Learning is learner-centred, involving dynamic classroom approach to stimulate learners' critical response to solve problems by applying theoretical and technical knowledge, provided by instructors and acquired through previous experiences/study. Significantly, in such hands-on approach aimed at developing learning processes oriented to structured problem-solving education, instructors have their role to evolve to process facilitators, guiding learners' active exploration of actual (and factual) challenges and problems that they will typically encounter when either applying their learning subjects to real situations. PBL Facilitators challenge learners to develop their technical proficiency and critical thinking skills, as well as teamwork collaborative attitudes and skills to maximize problem solving capability.

As collaborative process, PBL starts from questions to be investigated by providing a full array of hypotheses and explanations. Thus, learners are compelled to critically discuss their ideas face with other learners' ideas, being encouraged to challenge them and to devise new ones out of ongoing problem-solving debate. The five steps of the process along which PBL usually deploys are effectively met when joined by Continuous Improvement (CI) methodologies and, specifically, Lean Six Sigma, particularly within a framework of interventions driven towards process optimization in a wide range of potential contexts of application. CI and LSS drive learners to a systematic development of their competences (intended as the combination of knowledge, skill, and behaviour), while ensuring deeper knowledge of processes and stimulating towards Operational Excellence.

Based on learn-by-doing approach, LSS training educates the ideal LSS agent according to levels of increasingly complete skills.

The Define-Measure-Analyse-Improve-Control (DMAIC) methodology frames the entire optimization process, while Axiomatic Design (AD) is the tool to design the LSS training model, and it is the framework within which to manage the design process, providing criteria to critically analyse design. Axiomatic Design serves to include all relevant variables and scenarios, as well as contexts and situations (Arcidiacono, Giorgetti, & Pugliese, 2015; Arcidiacono & Placidoli, 2015). The first decomposition into functional, physical, and process domains categorizes intended functions, i.e. Functional Requirements (FRs), the means by which they are achieved, i.e. Design Parameters (DPs), and Process Variables (PVs). The second dimension of such decomposition is arranged as a hierarchy within the domains, and it can be achieved according to equivalence relations, based on partitioning. On such relations rely the concepts "WHAT we want to achieve" and "HOW we want to achieve it". The path from WHAT to HOW is the result of the process of matching FRs with DPs.

Our research aims at demonstrating to what extent Axiomatic Design supports PBL, in terms of synthesising suitable design requirements, solutions, and processes to be embedded for effective PBL. All this by following Aristotelian approach on the necessary hierarchical sequentiality of questions to be asked.

The engineering design process takes a set of specified inputs and conceptualizes a design to achieve the desired output effectively along four steps: Problem Definition, Creative Process, Analytical Process, and Ultimate Check. These same phases are applicable to map Blooms Taxonomy of cognitive learning (Bloom, Hastings, & Madaus, 1971) to developed relevant FRs, so that the key cognitive elements (Creating, Evaluating, Analysing, Applying, Understanding, and Remembering) are met by the FRs. The bases to develop the DPs answering the question “How to achieve it?” are rooted in PBL: process knowledge; initiative, enthusiasm, persistency; goal-oriented approach; teamwork; leadership; communication skills; analytical skill; time management capacity.

The design process means choosing the right set of DPs to satisfy the given FRs.

{FR} = [A] {DP}

{FR} = Functional Requirement vector, {DP} = Design Parameter vector, [A] = Design matrix, and the design matrix [A] is of the form:

$$\overline{[A]} = \begin{bmatrix} A_{11} & A_{12} & \ldots & A_{1n} \\ \vdots & & & \vdots \\ A_{m1} & A_{m2} & \ldots & A_{mn} \end{bmatrix} \qquad A_{ij} = \frac{\partial FR_i}{\partial DP_j}$$

The objective of the Axiomatic Design process is to satisfy a valuable learning experience (learning) through a blended classroom (teaching)										
FR TO DP DOMAIN CONVERSION										
FUNCTIONAL REQUIREMENTS - What we want to achieve		**DESIGN PARAMETERS - How to achieve it - Basis is Project Based Learning**								
Learning Objective	**Blooms Taxonomy - Cognitive Learning**	Process Knowledge	Initiative, Enthusiasm, Persistency	Goal Oriented Approach	Team working	Leadership	Communicatio n skills	Analytical Skills	Time Management Capacity	Computer Skills
Determine learning framework	Create		1			1				
Determine learning schedule	Create		1						1	
Frame question	Understand	1				1	1			
Identify driving Problem	Understand	1		1	1		1	1		
Apply functional competencies	Apply	1								
Apply discipline context functional tools	Apply	1								
Apply discipline context technology	Apply									1
Apply problem solving competencies - Groups/Teams	Analyze	1			1			1		
Create set of tangible products that address question	Create	1		1	1			1		
Share learning with class	Evaluate		1		1	1	1			

Figure 1. Schematic of design matrix for Project-based Learning model. (Arcidiacono et al., 2016)

In a good design this mapping should be satisfied by a singular DP to FR relationship or in other words, a particular DP should affect only its referent FR. This because the axiom of independence is violated due to multiple complex relationships, visible through the lack of a square matrix, and off-diagonal relationships.

The multi-level hierarchical (MLH) modelling technique applied by Trewn and Yang (1998) has been used to determine the dependence of a system reliability (Arcidiacono & Bucciarelli, 2016), and can be extended to the design matrix of the Project-based Learning model.

FUNCTIONAL REQUIREMENTS - What we want to achieve		DESIGN PARAMETERS - How to achieve it - Basis is Project Based Learning								
Learning Objective	**Blooms Taxonomy - Cognitive Learning**	Computer Skills	Time Management Capacity	Initiative, Enthusiasm, Persistency	Leadership	Communication skills	Team working	Process Knowledge	Analytical Skills	Goal Oriented Approach
Apply discipline context technology	Apply	1								
Determine learning schedule	Create		1	1						
Determine learning framework	Create			1	1					
Share learning with class	Evaluate			1	1	1	1			
Frame question	Understand				1	1		1		
Apply problem solving competencies - Groups/Teams	Analyze						1	1	1	
Identify driving Problem	Understand					1	1	1	1	1
Create set of tangible products that address question	Create						1	1	1	1
Apply functional competencies	Apply							1		
Apply discipline context functional tools	Apply							1		

(grey)	Independence
(hatched)	MLH Optimization
(dotted)	Constrained by higher level DP optimization

Figure 2. MLH Optimized Design. (Arcidiacono et al., 2016)

The Axiomatic Design methodology synthesises the analyses of suitable design parameters to optimize a product or a process.

2 Ideas

Lean Six Sigma and related process management methodologies could provide the perfect integration with Collaboration Engineering and the Collaboration Ontology that has been developed so far, to create a database for statistically quantified optimization process based on real case scenarios, which can be accessible to users who are not engineers. This would act as an archive for research studies, as a pool for best practice implementation, and could drive studies to enhance LSS methodology as effective optimization strategy. Moreover, this could lead to several applications of LSS-based PBL and to an increase the Collaboration Ontology database, so that all practitioners and scholars involved could “speak the same language”.
Challenges are data collection and data reliability, as well as implementing LSS as shared language. Moreover, since LSS projects are mostly conducted for private customers, ideally such integrated approach could be experimented in the public sector, such as in schools, hospitals, and other public institutions, to optimize processes and promote a shared culture of optimization processes.
All this could be dealt with implementing further participative exchange, with both academia and LSS consultants involved in a continuous exchange of data, building a corpus of shared – and shareable – knowledge and creating a well-structured procedure for project implementation, to ensure the correct qualitative and quantitative research methods to achieve usable data.

3 Conclusions

In this paper, we presented a first attempt to integrate Collaboration Engineering with Lean Six Sigma principles applied to Project-based Learning.

On the one hand, collaboration is a social and interactive process, where participants join efforts toward a shared common goal.

A Group Support Systems (GSS) can improve the productivity of collaboration work by structuring activities and improving communication.

On the other hand, LSS offers a unique methodology integrating a shared language, statistical measuring and effective process management techniques, using Axiomatic Design to structure and optimize the training model needed for Project-based Learning. Speaking a common language allows to improve interfunctional problems where people with different competences are involved.

Drawing on Collaboration Engineering and the LLS logical model, the paper explored the use of a collaboration ontology to capture and share knowledge about collaboration work and processes.

As upcoming progress of this research, we plan to develop new functionalities for the generic GSS that will reduce the experience needed to design and execute collaboration processes. In this context, we plan to use the collaboration ontology for information retrieval and machine learning approaches. Data and information collected with the generic GSS and the ontology constitute the basis for:

- learning recommendation for collaboration tasks;
- retrieval of matching collaboration tasks;
- Fuzzy Collaboration Task Matching.

In details, re learning recommendations, based on data collected from previous collaboration processes, we want to learn relations combining them with the LSS principles. Then, based on the learned relations, we want to recommend collaboration tasks fulfilling certain conditions.

As for retrieval, similar to the recommendations described above, collected data can be used as the basis for learning relations. However, in contrast to the first scenario, here the goal is to support collaboration engineers.

As regards Fuzzy Matching, the fuzziness of information has been also taken into account. Based on the collaboration ontology, we could introduce a Fuzzy Matching method that can help users in finding interdisciplinary collaboration processes.

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