Dealing with Complexity as a skill, complexity in an Engineering curriculum;

A curriculum analysis based on the Cynefin Framework

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1. INTRODUCTION AND CONTEXT

The last decades complexity science has developed into an interdisciplinary framework that helps to make sense of the behavior of living and adaptable systems. Typical examples of these complex adaptive systems include: our immune system, the brain, stock markets, companies and the internet [1]. In the field of engineering some new technologies emerge so rapidly that they disrupt the business models of entire industries. In these environments engineers have to create resilient solutions that work.

As educators of business engineers we are aware of these dynamics in the business and engineering environment. In a search for models that can help to understand these phenomena we encountered the comprehensive and widely cited Cynefin Framework [2, 3]. In several discussions the framework helped us to make sense of many of the dilemma's business engineers encounter in the real world. It also made us aware that the business engineering curriculum might not enable students enough to deal with these dilemmas. This brings us to the research question of this paper:

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To what extent does the Business Engineering curriculum of the University of Applied Sciences in Utrecht enable bachelors to find business solutions in the complexity contexts of the Cynefin framework?

The first part of the article will explore complexity and describe the Cynefin framework. The second part describes the research strategy and relate the business engineering curriculum to the Cynefin framework. Finally we will draw conclusion and describe possibilities for continued research in this area.

2. COMPLEXITY LITERATURE

In his pioneering article Weaver (1947) [4] first coins the term of organized complexity for problems that involve dealing simultaneously with a great number of factors which are interrelated into an organic whole. According to Weaver studying these systems holds the key to the science of the century. In 1984, a divers interdisciplinary group of prominent scientists and mathematicians met in Santa Fe to continue working on this ‘emerging syntheses in science’ and created an influential institute. Based on her work at this Santa Fe Institute Mitchell (2009) [1] summarizes the work that has been done and defines a complex system as: ’a system in which large networks of components with no central control and simple rules of operation, give rise to complex collective behaviour, sophisticated information processing, and adaption via learning and evolution’. She further states that these simple rules produce complex behaviour in hard to predict ways and that the macroscopic behaviour of such systems can be called emergent.

Boisot & Mckelvey [5] bridge complexity theory to organisations. They do this by stating that variety is a proxy for complexity. Ashby’s law of requisite variety states that ‘Only variety can destroy variety’ [6]. This means that in order to survive organisations have to mirror the variety of the imposed environment. Based on these assumptions they divide the (Ashby) space in which organisations are operating in ordered, complex and chaotic regimes of variety. Each of these regimes require different ways of acting in the world to create solutions. In the ordered regime linear models are usable. The complex and chaotic regimes are non-linear by nature or as Boisot and McKelvey call it: the Paretian world.

Snowden & Kurtz [2] relate complexity theory to the world of knowledge management and decision making. In 2003 they introduced the Cynefin framework and in 2007 Snowden & Boone published ‘A leaders framework for decision making’ [3]. The term Cynefin illustrates the evolutionary nature of complexity including the inherent uncertainty. Cynefin is a Welsh word, which can be translated into English as 'habitat' or 'place of multiple belongings' or the German term ‘heimat’. The Cynefin framework is a sense-making framework that distinguishes the situation of organisations in four contexts. The Cynefin framework houses Chaotic, Complex, Complicated and Obvious contexts.

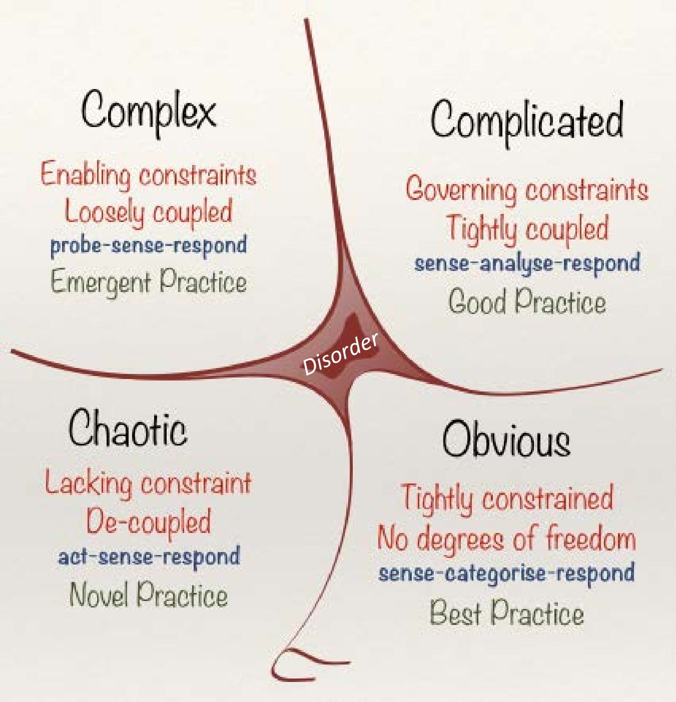

Figure 1 Cynefin framework [7]

According to Puik & Ceglarek [8] the state of relevant knowledge is the most important parameter to determine in which of the four contexts an organisation, system, or design process is currently located. This implicates that a context can change state when new knowledge is developed.

According to the Cynefin framework each context requires a different method or approach to search fitting solutions. The main characteristics of these contexts are:

- OBVIOUS: the relationship between cause and effect is obvious to all. The approach is to *Sense* the situation- *Categorize* it and *Respond* with the correct standard operating procedures. A **best practice** can be found.
- COMPLICATED: the relationship between cause and effect can be separated over time and space and requires some form of investigation and the application of expert knowledge. The approach is to *Sense* the situation - *Analyze* it with expert knowledge - *Respond* according to predictive planning rules. There will be several **good practices** that will fit to the situation.
- COMPLEX: the relationship between cause and effect can only be perceived in retrospect, but not in advance. The approach is to *Probe* the situation with coherent actions – *Sense* the reaction and *Respond* by amplifying or damping solutions. A fitting **practice can emerge** from the situation.
- CHAOTIC: there is usually no relationship between cause and effect perceivable. The approach is to *Act* to bring stability, *Sense* the reaction and *Respond* swiftly. **Novel practice** can be discovered.

In the centre there is *DISORDER*: the state of not knowing what type of contexts you are in. The risk here is that people will revert to their own comfort habitat in search for solutions and taking decisions.

3. BUSINESS ENGINEERING CURRICULUM IN RELATION TO CYNEFIN

To answer the research question the Business Engineering curriculum was analysed. The professional profile and the content of the courses were compared with the contexts of the Cynefin framework by looking at the methods students learn to search for solutions. These methods represent the state of relevant knowledge of the business context taught in the course and were compared with the characteristics of the Cynefin contexts in the previous paragraph. In cases of doubt we referred to the Cynefin articles mentioned in this paper.

The analyses were done by two teachers with in-depth knowledge of the curriculum because they are involved in its design and execution and by a researcher with a background in engineering and applied science methodology. Decisions were made based on consensus.

The degree profile is based on two sources. To go into more detail we need to look at these two sources for the curriculum, viz : the professional profile of the Bachelor of Engineering [9] and the methodology for Field Problem Solving in organizations described by Van Aken, Berends and van der Bij [10].

The professional profile of the Bachelor of Engineering [9] was developed by Dutch Universities of Applied Science. This profile covers 13 different engineering programs and leaves room for Universities to create their own engineering profiles. The main goal of the Bachelor of Business Engineering curriculum of the University of Applied Sciences in Utrecht is to teach bachelors to solve ‘complex multidisciplinary problems … by means of systematic analysis, research and the (re-) design of business processes’ [11].

When we compare this goal to the characteristics of the Cynefin framework, there seems to be a contradiction. Students are taught to solve complex problems, yet the steps that are described are suitable for the complicated domain, since they first Analyze the situation with expert knowledge before they Respond to it.

The other source for the Business Engineering degree profile is the methodology for Field Problem Solving in organizations described by Van Aken, Berends and van der Bij [10]. This is a design-oriented and theory-informed method that aims to design solutions to business problems at an academic level. The heart of this method is the problem solving cycle. This cycle presents 5 steps circling the problem mess to solve business problems (p. 37).

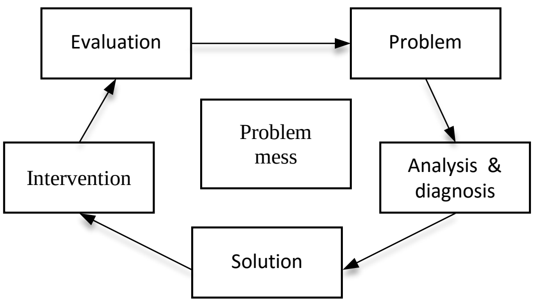

Figure 2 Field Problem solving cycle van Aken e.a. [10]

The Field Problem Solving (FPS) method has a dominant role in the curriculum. The curriculum starts with a course that introduces the FPS method in the second half of the first semester (20 weeks). Then students use the method in four out of six 5 EC projects in semester 1, 2 and 3. After this students have an internships in semester 4 and one in the graduation semester 8, in which the use of the Field Problem Solving method is mandatory. In the multidisciplinary engineering projects in semesters 5 and 6 other methods can be used. These methods are complementary to Field Problem Solving and we will return to this later. All teachers get training in guiding students to use the Field Problem Solving method. At the same time the FPS method creates a framework for all other courses since in most of these courses the students learn the models and methods for analyses, diagnoses, solution design, change interventions, used in the five steps of FPS.

As we will see, the Field Problem Solving method primarily fits the characteristics of the complicated context but it has ways to take into account aspects of other contexts as well. First we elaborate on the aspects of the model that place it in the complicated context, than we look at other contexts.

Aspects of FPS that place the methodology in the complicated context

First Van Aken et al. [10] state that their Field Problem Solving method 'is best suited for business problems with a significant technical-economic component, while having limited political and cultural components. It can be used for ill-defined problems, but not to ill-defined, too 'wicked' problems.' Further they write that their methodology uses a 'rational design of strategy, structure and change'. This clearly fits the characteristics of the complicated context.

A second characteristic feature of the methodology is the emphasis on the step Analysis & Diagnosis, which must be conducted before the solution is designed. The most important purpose of this step is 'to explore and validate the causes and consequences of the problem'. This is also typical for an approach in the complicated context in which one first analyses and then responds . Furthermore, the exploration of causes refers to the construction of several hypotheses, that are subsequently validated, partly empirical. This corresponds to what Snowden calls 'We can derive or discover general rules or hypotheses that can be empirically verified and that create a body of reliable knowledge'. [2]

Another characteristic of FPS is that it is theory-informed. The use of this knowledge implies that one needs to be an expert to solve the problem, what is also a characteristic of the complicated context.

A final example of an aspect that places FPS in the complicated context, is that Van Aken et al [10] stress the importance of the justification of the solution in the design step. 'The cornerstone of the justification is the explanation by the student why he/she judges that the implementation of the solution will solve the problem.' This explanation only makes sense when one believes that it is possible to predict/forecast the future, which is only possible when one assumes causal relationships, another characteristic of the complicated context.

Aspects of FPS that take in to account complex contexts of business problems

In two ways characteristics of the FPS fit the complex context. A first complex aspect is the problem mess that is central in the problem solving cycle. This is 'a mess of issues, of opinions and value judgements on those issues, of interests, power and influence'. These factors correspond to what Kurtz & Snowden [2] describe as 'patterns, which arise through the interaction of various entities through space and time'. When one takes into account patterns like this, one operates in the complex context.

A second complex aspect is the role of creativity in the design of a solution. Van Aken [10] states that 'a creative jump' is needed to come to possible solutions. In complexity terms these solutions are emerging practices that occur in the complex context. Van

Aken contrasts this creative jump to the deductive logic that is needed in the analysis and diagnoses, but also in the solution design when it comes to comparing the expected behaviour and performance of the possible solutions

Other methods and their context according to the Cynefin framework

In most courses of the curriculum other methods than FPS are taught as well. These other methods were related to the Cynefin contexts in a similar way, based on learning goals in the course descriptions. Table 1 shows the results. All courses contain methods for a complicated context. Some contain also algorithmic or standard operating procedures that fit an obvious context. As can be seen from table 1 no course is fully aimed at a complex context but all courses in semester 6 handle some methods for a complex context. Complexity can for instance be found in the cases used in the course Systems Engineering, but the available literature provides methods aimed at controlling and at reducing complexity and uncertainty. The basic approach in the course as well is to step by step resolve problems in a sequential order, articulate goals per phase and consult experts bringing in their best practices. In none of the approaches a probe-sense-response is advocated thereby smothering emergence of yet unknown practices. Similar results were found for other courses that cover some complex methods.

Table 1. Methods in the Business Engineering courses related to Cynefin
(X= most methods, x = substantial part of the methods, x some methods)

Business Engineering Curriculum – Utrecht University of Applied Sciences, Study guide 2015/2016			Cynefin Context			
Semester	EC	Course	Obvious	Complicated	Complex	Chaos
1	5	Introduction to Business Engineering		X		
	5	Process Management		X		
	5	Project & Professionalization		X		
	5	Product & Production Technology		X		
	5	Field Problem Solving & Statistical analysis	X	X	x	
	5	Project & Professionalization		X		
2	5	Logistics	X	x		
	5	ICT & Finance	X	x		
	5	Project & Professionalization		X		
	5	Integrated Design & Innovation		X	x	
	5	Finance and Calculation	X	x		
	5	Project & Professionalization		X		
3	5	Marketing & Sales		X	x	
	5	Organisational Behaviour		X	x	
	5	Project & Professionalization		X		
	5	Supply Chain Management		X		
	5	Performance & Quality Management		X		
	5	Project & Professionalization		X		
4	30	Internship		X		
5	5	Financial Management	x	X		
	5	Quality, Health, Safety, Environment	x	X		
	10	Multidisciplinary Project & Professionalization		X	x	

	5	Business an IT		X		
	5	Project management		X		
6	5	Sustainable Business Development		X	x	
	5	Change Management		X	x	
	10	Multidisciplinary Project & Professionalization		X	x	
	5	Entrepreneurship and Innovation		X	x	
	5	Systems engineering		X	x	
7	30	Minor				
8	30	Graduation Project		X		

4. CONCLUSION AND RECOMMANDATIONS FOR FURTHER WORK

In this article we are driven by the interest to find out to *what extend the Business Engineering curriculum of the University of Applied Sciences in Utrecht enables bachelors to find business solutions in the complexity contexts of the Cynefin framework.*

The main method in the curriculum, Field Problem Solving by van Aken et al. [10], is part of almost all the courses in the four year program. It has a clear stance using a complicated perspective in approaching situations irrespective of the five different complexity-situations described in the Cynefin framework. A first conclusion can be that the main method in the curriculum does emphasize the use of tooling for complicated situations rather than actively interact with the context in order to assess the appropriate approach.

The other methods in the curriculum were also related to the different complexity contexts, a summary of which was presented in table 1. From this table it is obvious that the main habitat of a Business Engineer is the complicated context. In the program no explicit distinction is made between complex and complicated situations. The curriculum however does acknowledge, especially towards the end of the program, the complex domain as relevant in assignment and case material. The question remains whether a program aimed at skills for the complex domain would be appropriate for full time students. Possibly just the discussion regarding the strengths and weaknesses of the complicated approach would suffice for bringing awareness of its limitations.

Between complicated and obvious situations an implicit distinction is made only. There is no attention for the chaotic context in the Cynefin framework. This means students are taught to approach all situations in more or less the same way with the same set of models and methods and are not made aware of differences between the contexts. This can be a problem since many real-life problems, especially towards graduation time can be placed in the complex context. In relation to this, further research is recommended to find out if business engineering students only need to know the limits of their habitat or if they need more methods in the complex context since a lot of business problems occur in this context.

In performing the analysis some limitations emerged. In the analysis underlying table 1, methods for individual professional skills or team performance were not taken into account. These contexts have a smaller social scale relative to the scale of an organisation where most methods for business improvement are used. To avoid interference only the latter were included in the analysis and related to the Cynefin contexts in table 1. On the smaller social scale, enabling constraints like motivation and reflection are important, which indicates these contexts are complex. It was striking to see that the dominant methods of the curriculum for these small scale social contexts, have a complicated nature. This indicates that more analysis with Cynefin of the curriculum at the team or interpersonal level could generate valuable information. It would also be interesting to analyse the differences between the problem solving approaches and the approaches for social interaction and interventions in relation to the Cynefin framework. This could be helpful to further identify relevant variables for the didactical approach of the business engineering program.

Another limitation is that we did a case study of the bachelor program Business Engineering of the University of Applied Sciences in Utrecht. This single case cannot be representative for engineering education in general, but is an interesting case to study since business engineers directly apply engineering principles to find solutions in the vibrant business environment. A study including a wider group of similar programs or across the engineering domain, could help to determine approaches to deal with complexity in developing educational programs.

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