Chapter 6
Conceptual Mapping, Visualisation, and Systems Thinking in Engineering

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ABSTRACT

Diagrams and maps have uses beyond the purely technical representations that engineers routinely use as part of their work. Diagrams can also help to clarify and resolve non-technical aspects of an engineering project, by visualizing hidden assumptions, values, and priorities that might remain tacit and unresolved in a purely technical discussion. This chapter shows how systems thinking and mapping allows soft interpersonal and social aspects of an engineering project to be represented and discussed alongside hard technological activities. Any map or model of a complex and dynamic socio-technical system requires simplifying assumptions. Complex adaptive systems theory provides a conceptual framework for identifying the limitations from different types of simplification. Examples from educational technology and from mining engineering show how various types of conceptual map can help in clarifying, negotiating, and combining different perspectives on technologies in a complex human context – to overcome barriers of specialist language and tacit assumptions.

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INTRODUCTION AND BACKGROUND

Engineers have always used discipline-specific forms of visual representation to develop and communicate specialist knowledge – engineering drawings, circuit diagrams, flowcharts, etc. Computer-aided design tools have transformed the way that engineering professional work is done. So it is fairly safe to assume that most engineering and IT professionals will already use some computer-based tools to develop visual representations or simulations of their products and processes: building structures, electronic circuits, chemical plants, manufacturing processes, computer systems, mining operations and so on. This includes project management tools such as critical path analysis and Gantt charts. This chapter explores the use of the same underlying communication process, using visual representations to develop and communicate knowledge, but focusing on the more messy and contested aspects of engineering work, where opinions, assumptions and cultural values need to be taken into account.

Many of the 'harder' aspects of engineering knowledge are well established and accepted within specialized disciplines, and the diagramming conventions are taken for granted. This is not the case when diagrams and other illustrations are used as conceptual tools for articulating and questioning 'softer' knowledge – the social and cultural aspects, the tacit assumptions, the differences of attention, focus and perceptions. In professional work, social and cultural assumptions often need to be surfaced and negotiated.

Systems thinking combines the hard and soft, recognizing that technologies arise from and are physical embodiments of human social activity. Soft Systems Methodology (SSM) arose from the failure to transfer systems engineering (goal seeking and optimization) to the management of organizations (Checkland, 1990). This is because many of the theories underlying the practices of organization leaders are tacit, and may have been learnt from experience of the business environment as it was several decades ago. SSM focuses on how to surface tacit assumptions and negotiate between the different worldviews of participants in a 'problem situation', using diagrams of 'purposeful activity systems', as a medium (Checkland & Poulter, 2006).

Most negotiating processes involve many exchanges of words, both written and spoken. Words are an essential part of professional communication, but they can have different meanings for different people, depending on their context and on the professional or cultural experiences of the individuals using them. Words such as 'feedback' and 'stress' have precise technical meanings, but are used much more loosely in everyday English. Similarly, if asked in a job interview about your 'background', would you choose to describe your professional experience, or your family, or your culture? Such differences in perceived meaning can lead to misunderstandings. Lawyers work to remove verbal misunderstandings by precise and standardized professional language, which then requires legal expertise to interpret. Similarly, engineering professional diagrams may be as hard for the non-engineer to understand as legal language is to a non-lawyer. However, there are some diagramming methods that can span specialist or local perspectives, to throw some light on hidden assumptions that may be blocking communication.

Senge (2006) defines systems thinking as the 'fifth discipline' which integrates four other aspects of human organization. Systems thinking is about understanding the complexity with which the personal and the team, the individual mental models and development of a shared vision, all interact and influence each other. Diagrams can show systemic patterns in these interactions, and Senge identifies a number of archetypal systemic human organizational patterns. Each archetype is a combination of reinforcing and balancing (positive and negative feedback) loops. The art in systems thinking is to see through the detailed complexity and identify the systemic structure of a problem. Systems thinking involves rising

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