Knowledge and Task Analysis Methods for Course Design

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Abstract

We believe that knowledge analysis and representation is one of the most important components in the process of course design. This paper reviews a number of popular methodologies for knowledge analysis and representation in education and training. We propose that the most effective method for knowledge analysis and representation is the knowledge and task analysis methodology derived from Pask and Scott's conversation theory as it is more conceptually coherent and practically effective than alternative approaches in the literature. We outline this methodology and show its derivation from first principles concerning how humans learn and interact together in learning and teaching situations. How this is being used to design online courses at the Defence Academy is described.

Introduction

Information and communication technologies (ICT) make it possible to realize new forms of education. However, unless we provide meaningful learning content, context and experience, the Web and other multimedia technologies are merely information resources and tools. Therefore, connecting and integrating useful knowledge in ways that are suited to the design of learning activities is crucial.

The aim of this paper is to bring this aspect of course design into plain view. First, the paper briefly refers to some existing ways to analyse and represent knowledge in education and training. Second, it proposes a methodology of knowledge and task analysis derived from the conversation theory (CT) of Pask and Scott (Pask, 1975; Pask, Kallikourdis, & Scott, 1975; Pask & Scott, 1973). Then it briefly describe how this methodology was used in the design of CASTE (Course Assembly System and Tutorial environment), an interactive learning environment that was developed in the early 1970s. The paper describes how we are using the methodology to design online courses at the Defence Academy. Course design for online learning as a ten-step process and how the knowledge and task analysis methodology is used both at the macro-level of overall course structure and the micro-level of learning design for individual lessons are described. How the methodology can be used to produce topic maps that support navigation between and within course components and as pedagogic aids in the learning of concepts and procedures is illustrated.

Analysis and Representation of Knowledge

There are many discussions about various forms of analysis and representation of knowledge. Several studies present different categories of knowledge, e.g. explicit or tacit knowledge, and declarative or procedural knowledge (Dorst & Kijkhuis, 1995; Giard & Gilles, 2001; Heylighten & Neuckermans, 1999; Morf, 1998; Novak, 1998). Explicit knowledge is knowledge we can easily show or explain to others, whereas tacit knowledge is knowledge that we build up over our lifetime in a variety of ways which we cannot readily show or explain. Declarative knowledge is described as knowledge of some object, event, or idea; it is also understood as knowledge of "knowing that" or conceptual knowledge (our preferred term). Procedural knowledge is regarded as "knowing how" (Novak, 1998). Both conceptual and procedural knowledge, having once been acquired with conscious awareness, may become tacit over time.

Jonassen, Beissner and Yacci (1993) also distinguish the structural knowledge that describes how declarative knowledge is interconnected. In our usage, conceptual knowledge encompasses both declarative and structured knowledge. As set out below, we refer to the analysis of conceptual knowledge as "knowledge analysis" and the analysis of procedural knowledge as "task analysis." In this context, we like to cite the "Law of the Simple and the Easy" (Confucius, c. 600 B.C., cited in Wilhelm, 1951).

> What can be explained can be explained simply; what can be done can be done easily.

The law refers to the wisdom of explaining and doing things in small steps.

Jonassen and colleagues in two books review the state of the art of knowledge analysis and representation. In Jonassen et al. (1993), methods for analysing and representing structural knowledge are presented. In Jonassen, Tessmer and Hannum (1999), methods for analysing and representing tasks are reviewed. Worthy and quite comprehensive though these reviews are, we believe that, conceptually, they suffer from two major flaws:

- the two kinds of analysis are treated as if they are unrelated, and
- the book reviewing task analysis covers aspects of both declarative and procedural knowledge.

With respect to the latter point, Jonassen et al. (1999) distinguish five general classes of task analysis:

- job or performance analysis: focuses on the behaviours engaged in by the performer;
- learning analysis: approaches focus on the cognitive activities required to efficiently learn;
- cognitive task analysis: focuses on performances and their associated knowledge states;

- content or subject matter analysis: examines the concepts and relationships of the subject matter; and
- activity-based methods: examines human activity and understanding in context.

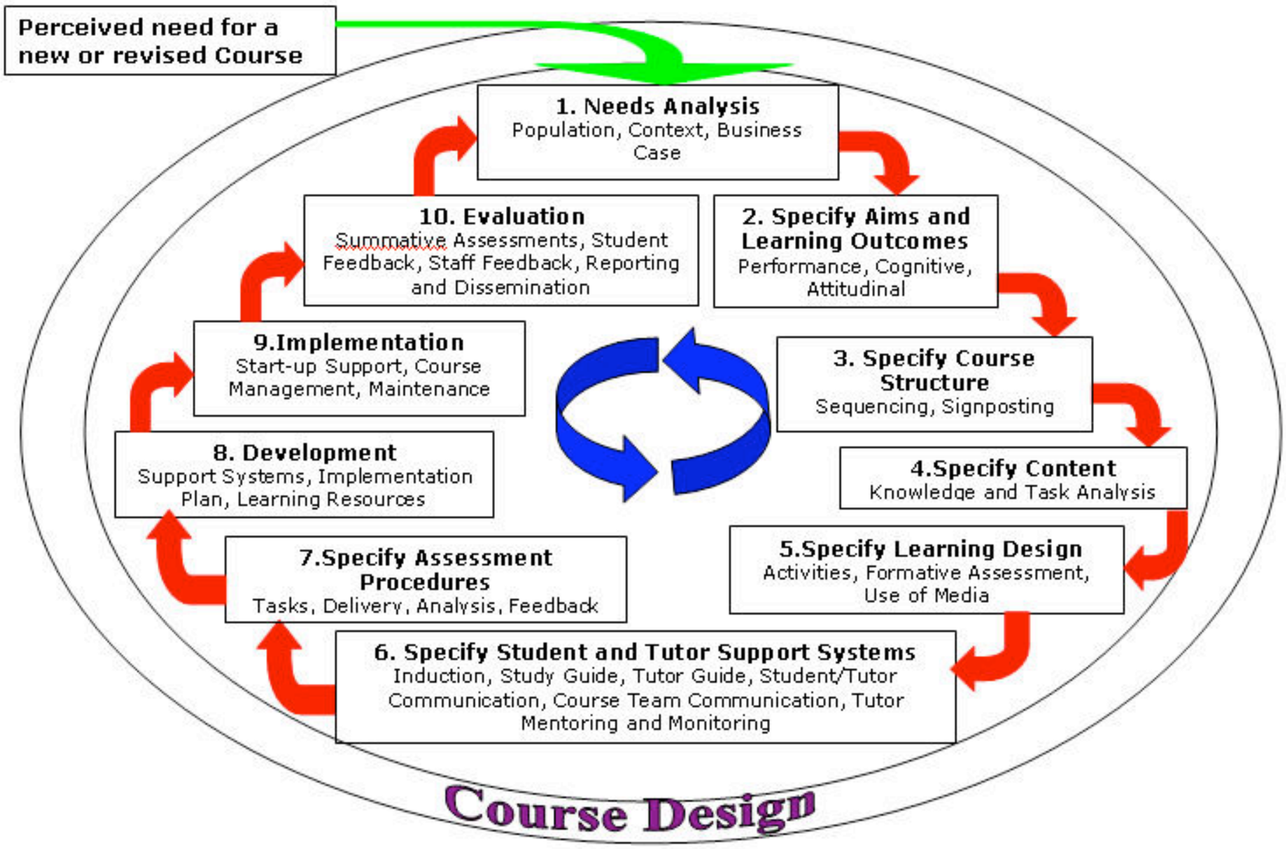
Each of these general approaches to task analysis focuses on different aspects of the job or task being learned. Content analysis and learning analysis address declarative knowledge and structural knowledge. Job analysis, activity analysis and cognitive task analysis address procedural knowledge.

We feel all these differences and overlaps to be unsatisfactory and confusing. We believe the knowledge and task analysis methodology, derived from CT, is a much more satisfactory approach for knowledge analysis and representation both conceptually and practically. This is because the CT methodology makes a clear distinction between conceptual and procedural knowledge and contains steps that ensure analyses of the two kinds of knowledge are carried out in complementary and coordinated ways.

Knowledge and Task Analysis as Part of Course Design

There is not space to go into all the stages in detail here — suffice it to say that we see knowledge and task analysis as a distinct and important step. We wish also to note that analyses may be carried out at different levels of granularity, from the level of whole courses down to the level of individual lessons and, indeed, individual concepts within lessons. Figure 1 is an overview of the processes involved in course design.

Figure 1: Course Design Processes



Any of the above activities may take place in parallel. At any stage of the design process, the outcome may be revised in the light of experience as indicated by the anti-clockwise arrows.

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Conversation Theory[1]

CT, as developed over three decades by Pask, Scott and others, serves as a useful conceptual framework that brings order and sense to the evolving and complex area of application known as e-learning or technology-enhanced learning. In this paper, we draw on CT as: (i) a theory of learning and teaching, particularly suited for understanding how to support effective student-centred learning when using learning technologies for the online delivery of resource based learning; (ii) as a source of principles of course design and the design of learning environments; and (iii) as a source a methodology for knowledge and task analysis, particularly suited for eliciting and representing the structure of course content in an online hypertext environment. Underlying assumptions of conversation theory include the following:

[1] The description of CT and CASTE given here is an abbreviated version of that to be found in Scott (2001).

- The brain/body system is a dynamic self-organising, "variety eating," adaptive and habituating system, subject to boredom and fatigue. As Pask often put it, "Man is a system that needs to learn"[2], thus the problem of motivation is not "that we learn" but rather what is learned and why.

- For humans, learning is also about the construction of symbolic representations, acquired through the conversational interaction and the inner dialogic processes — conversations with oneself.

- In conversation, narrative forms are constructed and exchanged. What is memorable is that which can be "taught back" (Pask & Scott, 1972).

Habitual forms of behaving and thinking evolve by proceduralisation. Proceduralisation may be guided and monitored by learning and teaching strategies. In conversation theory, remembering is understood as a dynamic process of reconstruction that is always contextualised and social (minimally, with no other person present, a psychological individual remembers with itself). If we do use the metaphor of memories being 'stored' in our brains and bodies, we should recognise they are also "stored in our environments including the brains and bodies of other people." This is a Pask aphorism that predates the more recently articulated concepts of "situated" and "distributed" cognition.

Minimally in a conversation the participants distinguish and learn about each other. Where a particular topic is under discussion, participants construct models of each other's models of that topic. The particular conceptions and misconceptions (kinds of understanding) that participants have of the topic in question can, following Aristotle and others, be broadly classified as "knowing why" and "knowing how." In conversation participants may share both kinds of knowledge, exchange theories, and present evidence in support of those theories. In this sense, conversation theory is a theory of theory construction and elucidation.

The Skeleton of a Conversation

The basic CT model is shown in Figure 2: the "skeleton of a conversation." It shows a snapshot view of two participants in conversation about a topic. The model distinguishes verbal, "provocative" interaction (questions and answers) from behavioural interaction via a shared modeling facility or "micro-world."

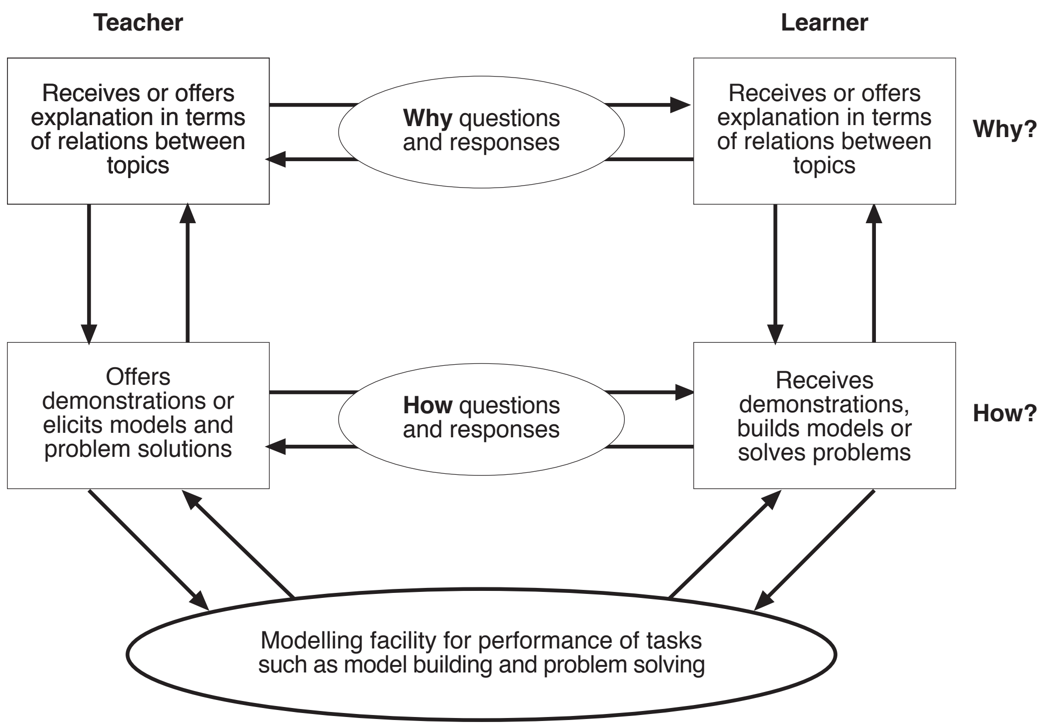
The horizontal connections represent the verbal exchanges. All such exchanges have, as a minimum, two logical levels. In the figure these are shown as the two levels: "how" and "why." The "how" level is concerned with descriptions of how to *do* a topic, i.e., procedural knowledge: how to recognise it, construct it, maintain it and so on; the "why"

[2] This is a paraphrase. For Pask's arguments in support of this proposition see Pask (1968).

level is concerned with conceptual knowledge: explaining or justifying what a topic means in terms of other topics. These exchanges are 'provocative' in that they serve to provoke participants to construct understandings of each other's conceptions and (possibly) misconceptions of topics and the relations between them.

The vertical connections represent causal connections with feedback, a hierarchy of processes that control or produce other processes. At the lowest level in the control hierarchy is a canonical world or "modeling facility" where the teacher may exemplify the topic by providing non-verbal demonstrations. Typically, such demonstrations are accompanied by expository narrative about "how" and "why" — the provocative interactions of questions and answers referred to above. In turn, learners use the modeling facility to solve problems and carry out tasks set. They may also provide narrative commentary about "how" and "why."

Figure 2: The "Skeleton of a Conversation"

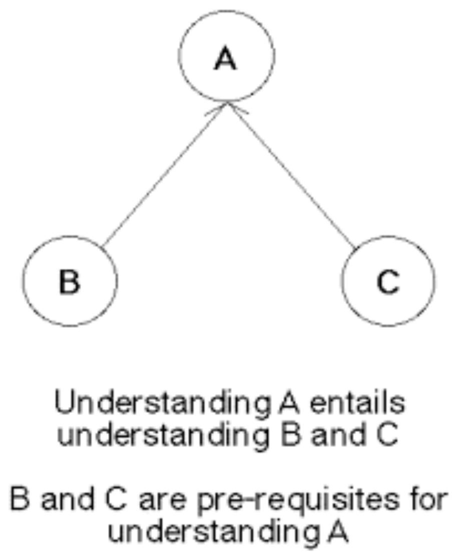


In ordinary conversation, "how" and "why" are intermingled. Topics are introduced and are or are not justified, exemplified and demonstrated, depending on the participants' perceptions of each other's needs. CT proposes that understanding implies both knowing why (conceptual knowledge) and knowing how (procedural knowledge). Understanding is demonstrated by teachback. Teachback involves showing knowing why, by providing conceptual definitions, explanations and justifications; and showing knowing how, by non-verbal performance or by verbal description of how to achieve goals and subgoals (solve problems, construct models, recognise or provide examples, perform skills).

The CT Knowledge and Task Analysis Methodology

In CT, knowledge and task analysis are complementary. Conceptual knowledge is represented using a special kind of concept maps known as entailment structures. Entailment structures are concept maps that impose partial orderings on topics showing how topics may be derived from one another or explained in terms of one another. Entailment structures show "what may be known": how new topics are understood, explained or defined in terms of other topics. A simple example is shown in Figure 3. Associated with each topic is the expository text that defines and explains that topic in terms of subordinate topics.

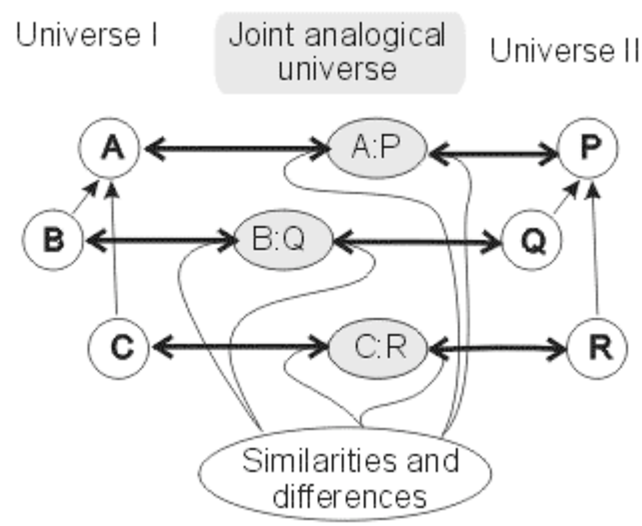
Figure 3: A Simple Entailment Structure



As well as relations of logical entailment, entailment structures may also show analogy relations between topics or subsets of topics. An example depicting an analogy is shown in Figure 4. The diagram shows two simple entailment structures in distinct universes of discourse related by analogy. Universe I is concerned with "means of grasping"; Universe II is about "means of walking"; the joint analogical universe is about "limbs and their uses." Topic A entails topics B and C; topic P entails topics Q and R. The analogy has the overall form "A is to B and C as P is to Q and R"; for example, "Hand is to finger and palm as foot is to toe and sole." The key similarity is one of structure; the key difference is one of function.

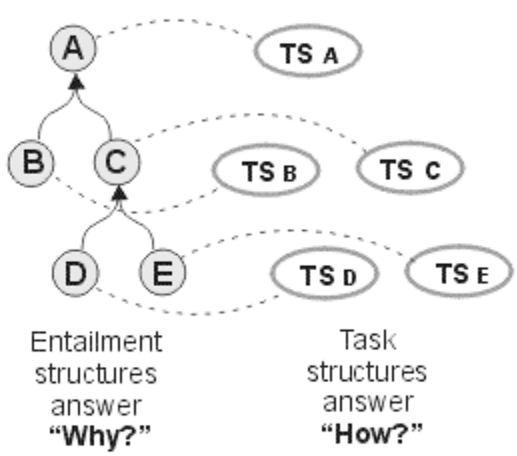
The important thing to appreciate about such maps is that they show possible ways of coming to know a body of knowledge. The structures show the forms that possible teaching and learning strategies may take.

Figure 4: Two Simple Entailment Structures Related by Analogy



For performance learning outcomes, the content of topics, their "how," needs to be specified operationally as the set of procedures the learner should be able to perform satisfactorily. In order to provide detailed descriptions of the procedures that constitute satisfactory performance, a task analysis and specify task structures is necessary, defined with respect to a "world" of possible activity, such as a modeling facility, a micro-world, a laboratory or workspace with apparatus. Task structures show 'what may be done.' They show the "procedural knowledge" or "performance competencies" that someone who understands a particular topic is deemed to have (Figure 5). For example, for the topic "hand," the learner could be asked to draw a diagram of a "hand" or assemble a "hand" from component parts.

Figure 5: An Entailment Structure with Associated Task Structures



Task structures may be represented in a variety of ways, for example, as a precedence chart showing order relations between the goals and sub-goals of a task or as a flow chart showing a sequence of operations, tests, branches and iterations. Figure 6 shows a precedence chart representation of a task structure showing the possible orders in which sub-goals may be achieved to achieve goal D. As an example, the diagram shows that both of the sub-goals A1 and A2 need to be achieved before sub-goal B1 can be achieved but A1 and A2 can be achieved in any order.

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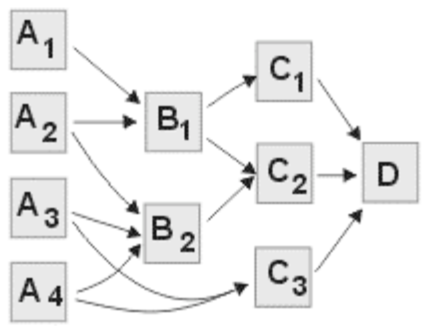


The Use of Knowledge and Task Analysis in the Design of CASTE

CASTE (Course Assembly System and Tutorial Environment) was developed by Pask and Scott (1973) in response to the need to provide learners with a description of a body of subject matter so that there could be 'conversation' between a computer-based tutorial system and the learner about learning strategies. CASTE presented subject matter topics in a way that supported holist and serialist learning strategies.[3] Using the conversational features of CASTE, system and learner agreed what was likely to be an effective learning strategy and established an associated "learning contract." This latter typically included the agreement that progress was contingent on the student successfully "teaching back" what he or she had learned so far. Using these contractual constraints, effective learning to "mastery" level (Block, 1971) was regularly achieved.

The main features of CASTE are shown in Figure 6. They are:

[3] Detailed descriptions of holist and serialist learning strategies can be found in Pask and Scott (1972). In brief, a holist strategy is one where the learner builds up or (if one is provided, as in CASTE) uses a broad picture of how a knowledge domain is structured in order to learn about several topics at once. A serialist strategy is one where the learner prefers to work on one topic at once, following a linear sequence through the subject matter.

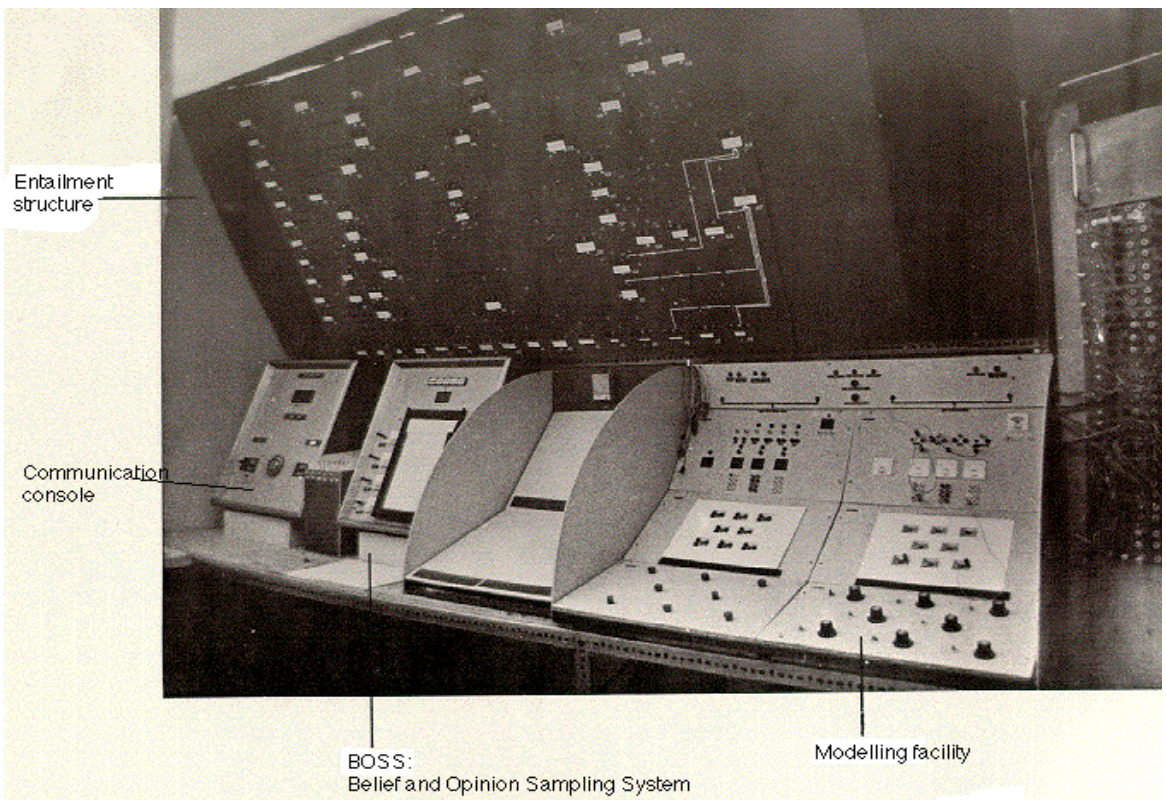
- An entailment structure for the whole of a course — an hierarchical form of concept map showing possible learning routes.

- A modeling facility used for demonstrating topics and assessing understanding, in accordance with well-specified task structures.

- BOSS (Belief and Opinion Sampling System) for sampling students' uncertainties about topic choices and topic content.

- A communications console affording different transaction types, e.g., "state aim," "select topic," "elicit demonstration," and "submits explanation." When following a holist learning strategy, students were permitted to work on more than one topic at once. For serialist strategies, topics were worked on, to mastery, one at a time.

Figure 7: The Main Features of CASTE



The basic rules of the system were that:

- learners could only work on a topic, if they had demonstrated that they understood a set of prerequisite, subordinate topics from which the topic in question could be derived (there may be several such sets if there are analogies depicted in the entailment structure);

- having received one or more demonstrations of a topic the learners were constrained, at some stage, to producing a different demonstration to show that they understood the topic (all the transactions at the modeling facility were mechanically detectable and scorable).

A typical transaction sequence for learners would be:

1. *Explore* the subject domain by accessing brief descriptions of topic content and examining the relations between topics shown on the entailment structure.

2. *Aim* for a topic as one they wish to come to understand. The topic must, of course, be one that she does not already understand.

3. *Choose* topics to work on. These may be one or several; they must be subordinate to the aimed for topic or be the aimed for topic itself. Furthermore, all topics "worked on" must have sufficient subordinate topics already understood (as in rule 1, above).

4. *Request* demonstrations of the topics worked on. This step is optional as learners are free to omit demonstrations if they feel they can proceed without them). The demonstrations typically take the form of written text and graphics showing how to set up a model on the modeling facility.

5. The learner "explains" the topics she has worked on by constructing models for the topics but (as in rule 2) that are not just copies of the demonstrations she has received.

6. If the (non-verbal) explanation is correct, the topic in question is marked understood. If not, the learner is directed to request further demonstrations.

7. At some stage, by some route, the learner is led to demonstrate his understanding of topic(s) at the top of the entailment structure (the head topic(s)) and the tutorial is over.

Overall understanding was ensured because (i) learners accessed topics in a logically coherent sequence, supported by the entailment structure and the expository narrative associated with each topic; (ii) the task structures guaranteed that in explaining a particular topic by modeling activities, learners also demonstrated understanding of “how” for all entailed subordinate topics; and (iii) assessment was by teachback, as defined above.

As noted, BOSS was used to study learners’ uncertainties about topic content and about their strategic plans. Clear differences between learners following serialist and holist strategies were observed. Learners following a serialist strategy would typically be confident about the content of a topic selected to be worked on but would exhibit uncertainty about the topic sequence they intended to follow. In contrast, learners following a holist strategy would not be so confident about the content of topics (usually more than one) selected to be worked on but would be quite confident about the topic sequence they intended to follow.

The Use of Knowledge and Task Analysis in Courses on Military Knowledge

Cranfield University supports military colleagues at the UK Defence Academy in the delivery of a wide range of educational courses relevant to the needs of the defence sector. We have been engaged in developing quality Web-delivered distance learning courses for the British Army as part of the Officer Career Development (OCD) initiative. The OCD initiative aims to provide "life-long learning" for Army officers up to the point of retirement. Our particular concern has been with developing courses aimed at officers in the early and middle periods of their careers. These are known as Military Knowledge 1 and Military Knowledge 2 (MK1 and MK2) and provide in total some 200 hours of self-directed learning, covering, as the titles suggest, basic knowledge of military doctrine, service functions and organization, together with coverage of relevant science, technology and project management topics. For logistical reasons, MK2 was the first of the courses, as of December 2004, to go live online. (See Mackain-Bremner & Scott, 2006 for more information about these programmes.)

The MK course is divided into parts, modules, sections and lessons. Each lesson is further divided into as many as five topics. The MK courses are structured in such a way as to give total freedom to the student in terms of the order in which each lesson and, indeed, each topic or subtopic is accessed. Sound instructional design principles were applied to the intra-lesson navigation but we also wanted to provide students with a visual representation of a relatively complex course and, ideally, a mechanism for browsing and launching lessons. Our solution (shown in Figure 8) was to create an interactive Knowledge Map which, as well as providing an overview of how the course is structured, allows macro navigation at course level down to the level of an individual lesson.

Within a particular lesson, students are permitted to browse lesson content or to go directly to any given topic within the lesson via the lesson's topic menu internal navigation. Students are also provided with an entailment structure type Lesson Map which shows how the lesson is structured and allows them to navigate to a given topic or subtopic. An example is shown in Figure 9. The learning design used for lessons follows the principle that for each topic there is a clearly defined learning outcome and associated task as a self-assessment activity.

Figure 8: MK Knowledge Map

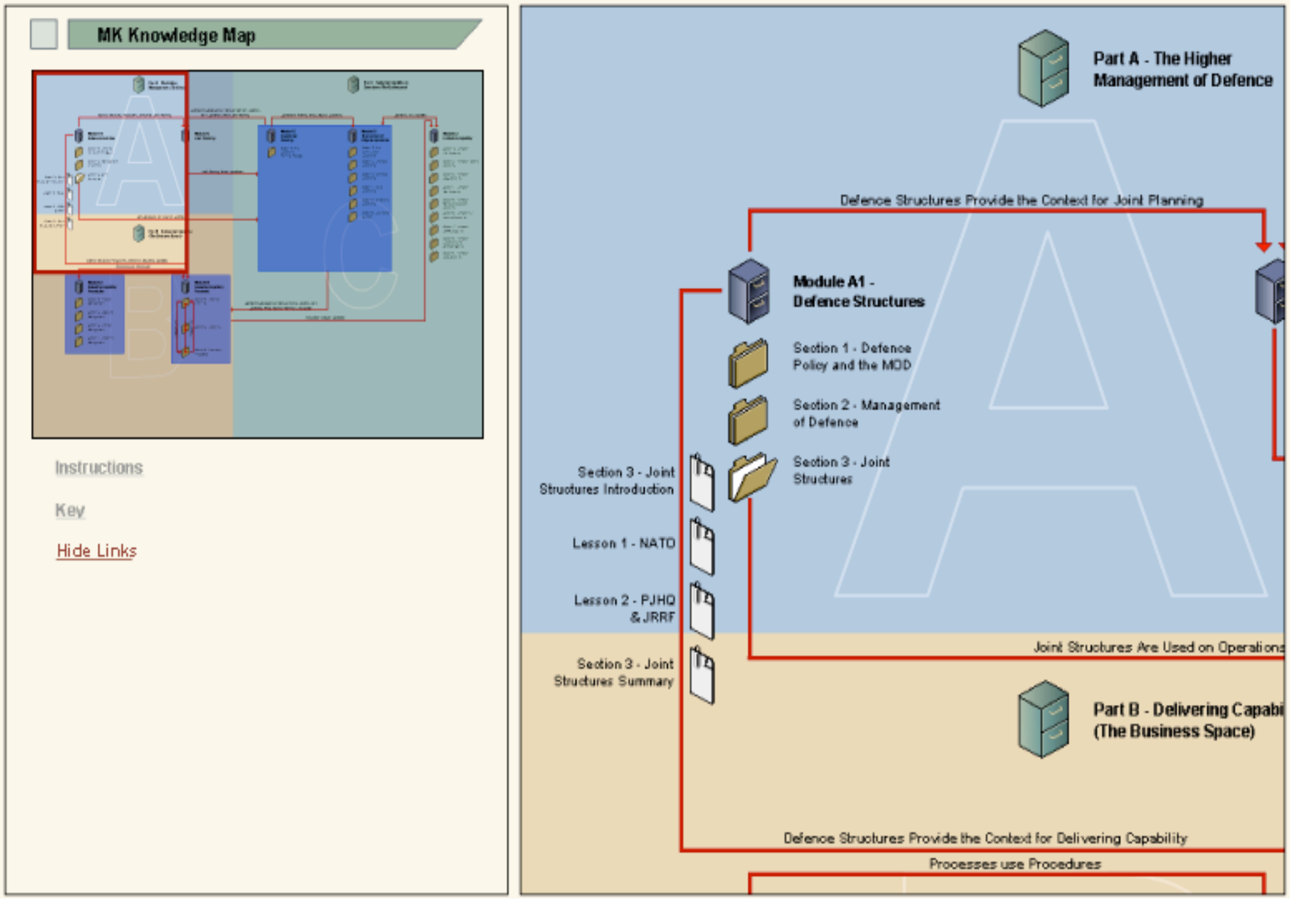
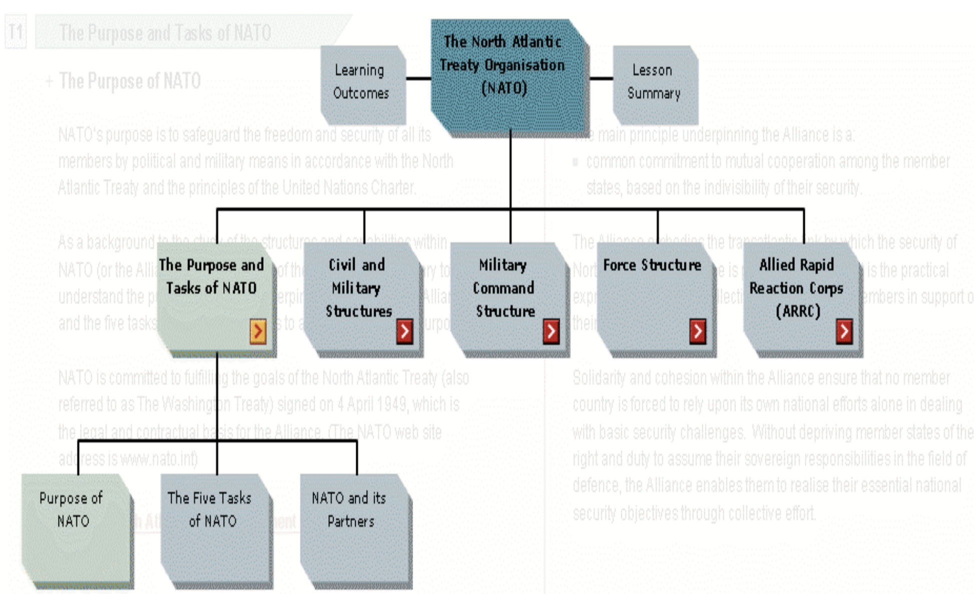


Figure 9: MK Lesson Map



We are currently engaged in an in-depth evaluation study of design features of the MK courses, using focus groups, interviews, questionnaires and observation studies. Our aim is to further validate our principled approach to course design and to identify ways in which the approach may be improved in the future.

Data so far indicate that learners do appreciate and make use of the various design features. However, there are interesting individual differences in approaches to learning. In particular, a subset of learners makes consistent use of the Knowledge Maps and Lesson Maps to navigate through course content in nonlinear ways. This is indicative of a holist learning strategy. Other learners prefer to move between lessons and work through lessons in a linear sequence. This is indicative of a serialist learning strategy. We hope to publish more detailed findings in due course.

Concluding Comments

This paper can give only a brief overview of the CT knowledge and task analysis methodology. We believe this methodology has much to contribute not only to learning design but also to the broader area of knowledge analysis and knowledge visualisation.

With respect to the latter, there is now a wealth of tools for concept mapping. None of them support the complementary approach to knowledge and task analysis found in CT. We are thus keen to raise awareness of the CT methodology in the hope of encouraging the development of more sophisticated and effective tools.

The MK courses use topic maps to support learner navigation and tracking in a CASTE-like manner. However, adaptive teaching with progress through lesson content contingent on summative assessment attainments has not yet been implemented. The next step for the Cranfield e-learning research team is to prototype such a system. This will serve as a CASTE-like flexible learning environment where learning can be studied under different regimes, ranging from free learning, where there are no constraints on how learners progress through lessons, to adaptive regimes, where progress is contingent on mastery of lesson content.

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