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A Theoretical Model for Content Analysis in the Development of Hypermedia-Assisted Learning Material

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Content analysis plays an important role in the development of hypermedia-assisted learning systems. To achieve the effectiveness of content analysis, it is necessary to employ an appropriate theoretical model. This paper presents a three-dimensional theoretical model that has been developed based on learning and instructional design theories. By applying the model to the content analysis for the design of hypermedia-assisted self-study procedures in engineering, one can increase the effectiveness of the entire design process, and would enhance the quality of the developed teaching-learning system.

INTRODUCTION

The use of computers in the teaching process should be regarded as a supplement to existing methods and material for instruction. A significant amount of systematic and complex research has provided developers with comprehensive information on how to convert teaching material into relevant computer programs. So far only a few have addressed the role and method of content analysis in the development of computer software, taking into account educational-psychology and instruction design theory and technical requirements.

This paper describes a theoretical model used as a framework for content analysis in the design of hypermedia-assisted self-study procedures. The model is based upon instructional design theories presented by Reigeluth [1]. In the application of the model, the content is analysed with regard to three aspects: the content organisation, the sequencing strategies and the instructional approaches, all forming a three-dimensional model. The analysis results demonstrate the effectiveness of the method.

THE ROLE OF CONTENT ANALYSIS

Proper technology should be used to supplement existing teaching methods. How it should be supplemented, and what the criterion is for such supplementation, are critical questions. Content analysis based on cognitive science and instructional design theories is an important element of this endeavour.

In the design of Computer-Assisted Instructions (CAI) it is not uncommon that subject matter experts are keen to develop computer-assisted learning systems based on their teaching material, teaching experience and intuition. In designing such teaching systems they may not be familiar with the learning and teaching theories used for such development. Also, they may not be able to carry out any substantial analysis of the content based on educational psychology and instruction design theories. Such work may result in a less effective final product, leading to inefficient use of the technology. From this point of view, it is essential to carry out content analyses systematically with respect to educational psychology and modern instructional design theories. Apparently, content analysis should be the prerequisite for designing and implementing computer-assisted instructions in order to achieve optimal learning outcomes.

Computer-assisted learning systems have generally been developed either by converting existing courseware or by writing special purpose software. The design requirements of educational software differ from both the design of printed teaching material and other types of application software. It requires a learning system that is able to accommodate such

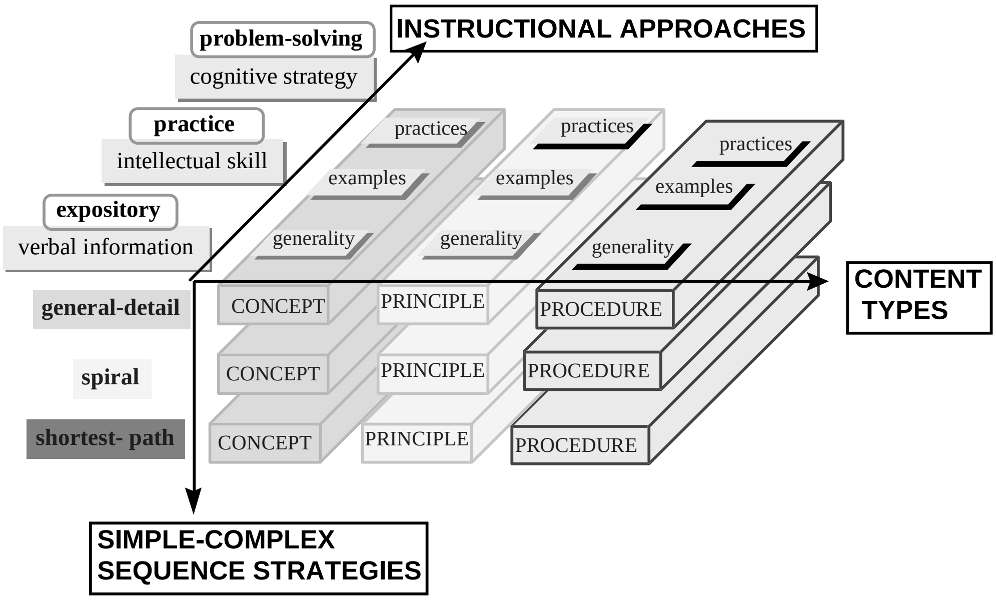

Figure 1: A three-dimensional theoretical model.

aspects of the learning environment as educational goals, learner characteristics and physical settings etc. Furthermore, to achieve the balance between learning interface and user interface, the systematic integration of cognitive structures and pedagogical strategies should be considered elaborately [3]. A computer-assisted learning system should also provide an exploration environment that can be accessed by learners with a variety of learning styles, different perspectives and for different purposes. Obviously, the development of a computer-assisted learning system is a costly process due to these specific requirements.

Fortunately, with the development of powerful authoring tools, especially hypermedia technology, the cost and difficulty of the development of a learning system can be greatly reduced. Hypermedia is an information technology for organising information that allows meaningful, non-linear access to multimedia resources. It has great potential to integrate structural non-linear characteristics and instructional strategies for organising, representing and conveying subject domain knowledge. In hypermedia design, designers can easily use existing information or create it if not available. This requires that the design of a hypermedia learning system should underscore the selection and analysis of materials as an important part of the design effort. Therefore, the primary consideration in a hypermedia design situation should be to ensure that the central concepts, structure and instructional strategies of content are carefully preserved. From this point of view, the first step in successful design is to analyse the learning material thoroughly by following cognitive science and instructional design theories.

A THREE DIMENSIONAL MODEL AS THE FRAMEWORK FOR CONTENT ANALYSIS

An effective learning system is designed by following educational theories and rich teaching experience and it is therefore reasonable and effective to employ a framework of instructional design theories as analysis principles and the basis for the content analysis. In this paper, a three dimensional model based on some instructional design theories is described, as shown in Figure 1 [1]. Details of this model are not described due to lack of space.

The first dimension (*Content types*)

According to cognitive science, knowledge is a large body of information organised into elaborate semantic networks in the human long-term memory. These networks can be categorised into various types of knowledge in terms of human learning. The widely accepted classification of knowledge types is that they are declarative (knowing what), procedural (knowing how) and contextual knowledge (knowing when and how). This implies different characteristics for learning, storage, recall and transfer of information. Declarative knowledge is usually acquired by meaningful concept learning; procedural knowledge is learned by doing; while contextual knowledge is more likely obtained by problem-solving. Organising and representing the types of knowledge accordingly can greatly promote the acquisition, employment and transfer of knowledge. Consistent with cognitive theory, the constructs of subject matter content are basic building blocks which can also be classified into conceptual, procedural, and theoretical types [2].

The second dimension (*Learning Objectives*)

According to Gagne's taxonomy of learning objectives, three major learning objectives are verbal information, intellectual skills and cognitive strategies. Verbal information deals with the learner's understanding of the declarative knowledge within the subject domain. Learning an intellectual skill means learning how to do something of an intellectual nature that involves the learner acquiring the specific skills to correctly use the declarative knowledge. A cognitive strategy is an internal control process by which learners select and modify their ways of attending, learning, remembering and thinking [3]. Different types of content and learning objectives require different instructional treatment for most effective learning.

The third dimension (*Sequencing strategies*)

There are three sequence strategies in the literature. Brune's spiral sequence approach proposes that the same fundamental ideas of a subject should be taught at each grade but with increasing levels of sophistication. Ausubel's general-to-detail sequence strategy proposes progressive differentiation of more general and inclusive anchoring ideas. Gagne's *learning hierarchy* prescribes a parts-to-whole, *bottom-up* sequence, in which the most elementary parts at the bottom of the hierarchy are taught first, followed by progressively more complex combinations of the parts. Generally, these three major types of sequence are variations of the simple-to-complex sequence pattern which should differ, depending on the desired learning objectives and content types orientation. This means that each type of sequencing focuses on one type of content, other types of content become support and should be available at the relevant level.

Two levels of instructional treatment

Instructional treatment can also be directly linked to specific types of content and learning objectives. Macro level strategies are expository strategies, providing a meaningful context for the learning of declarative knowledge; intellectual skills strategy, providing a rich environment for learning intellectual skills by doing; and the cognitive strategy, presenting problem situations that require establishing cognitive activities by retrieving and employing appropriate knowledge. At the micro level, instructional strategies can be categorised into three primary components: a generality, examples, and practice items, which can be used for all three types of content components [2]. An appropriate integration of the content types, structures, sequences and instructional approaches can greatly optimise achievement of the desired learning outcomes.

THE APPLICATION OF THE MODEL IN THE DESIGN OF HYPERMEDIA-ASSISTED SELF-STUDY PROCEDURES

The general model described has been used to analyse content material in the development of the hypermedia-assisted self-study procedures for electrical engineering. This project is being carried out by the UNESCO International Centre for Engineering Education (UICEE). Content material selected is based upon the book *Basic Electrical Engineering: Laboratory and Tutorial Procedures* [4]. Work carried out to date shows the applicability of this method for content analysis. By applying this method, the content of the material is analysed with regard to three aspects: content organisation, sequencing strategies and instructional approaches. The model is shown in Figure 2.

THREE TYPES OF CONTENT

The book consists of eleven methodological units, each comprising five parts: objective, introduction, measurement procedures, tutorial problems and recommended references. Each unit deals with different types of knowledge, with emphasis being placed on procedural knowledge. The introductions contain major declarative knowledge, including concepts, indispensable notions, laws and principles. Measurement procedures allow students to gain procedural knowledge by carrying out experiments. Tutorial problems are oriented toward the development of cognitive skills embedded in the algorithmic procedures, which facilitates solutions. Finally, recommended textbooks help students to find comprehensive information concerning particular problems. The design of the material is consistent with, and supported by, this effective knowledge organisation and hence provides a basis for the integration of different instructional strategies.

LAYER-NESTED SEQUENCING STRATEGIES

The design of the self-study procedures is prominently featured in its three layer-nested sequence strategies. The first layer is a parts-whole sequence that deals with steps and sub-steps of a procedure at a physical level. The second is specification-to-generalisation strategy that deals with conceptual knowledge at a logical level. The entire structure of the book follows the third simple-to-complex strategy.

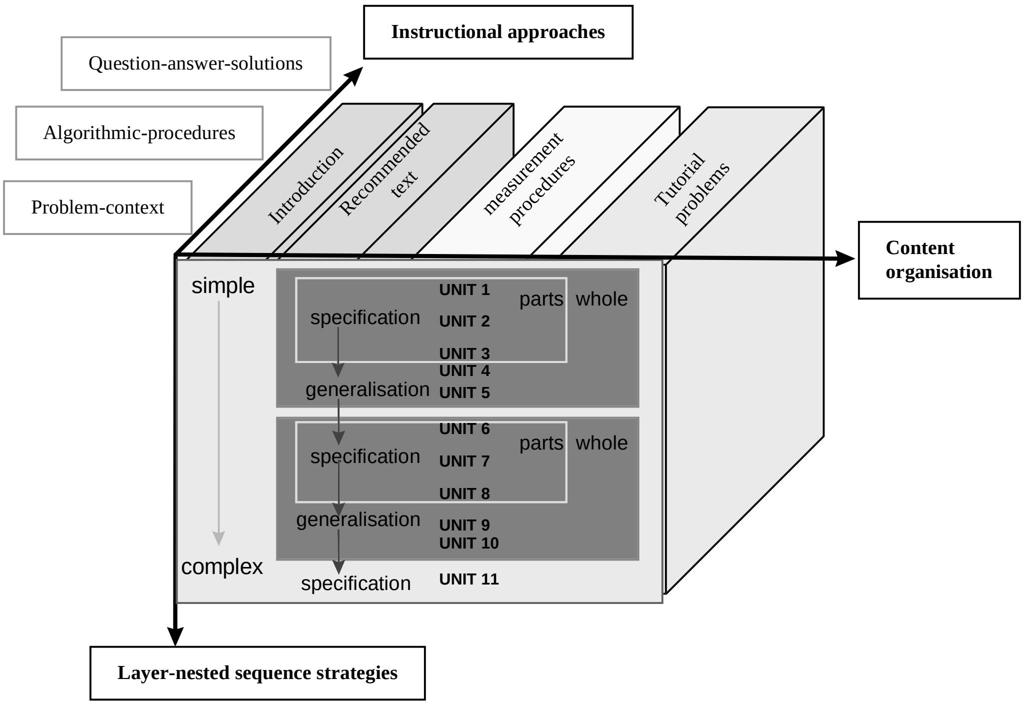

Figure 2: The structure and organisation of the content material.

THREE LEARNING OBJECTIVES

According to the third dimension of the theoretical framework, the learning objectives can be categorised into verbal information, intellectual skills and cognitive strategies [3]. Owing to the highly structured nature of the book, these objectives are evident to the learners.

Verbal information

Each unit in the book has a preliminary theoretical introduction, followed by an indication of where the relevant prerequisite theory can be found. The introduction contains the basic concepts and principles in the lecture notes, presented briefly in the light of the procedures and tutorial problems. In this way, students can read the introduction first before applying theoretical knowledge in practice, or they can find out what information and knowledge they need in order to solve a problem. The learning objective, verbal knowledge acquisition, is reached as a consequence of this learning behaviour.

Intellectual skills

The major objective of the book concerns the development of intellectual skills, and the declarative knowledge in the introduction sessions is designed to support this objective. The performance objectives defined in the instruction section are the elaboration of the unit objectives and are sufficiently specific and detailed to show progress towards the goals. Each performance objective defines a unique performance, which is a kind of capability that determines what the student can do. The algorithmic structure is used in the book to help students to conduct measurements step by step, as well as to motivate them to reach a correct solution, which is particularly suitable for laboratory and tutorial work.

Cognitive strategy

The significant characteristics of the material under analysis are that they are problem-oriented and algorithmically structured. In the book the description of the learning objectives associated with cognitive strategies is separated from the process of problem-solving. In other words, rather than being explicitly expressed, the desired outcomes are embedded in the content structure and algorithmic procedures. The focus is on what is being constructed by the learners. For example, the presentation of the tutorial problems provides an environment in which students are stimulated to apply verbal information and procedural knowledge to previously unencountered situations, thereby intensifying their knowledge and cognitive ability.

INSTRUCTIONAL APPROACHES

Differing from the dimension of instructional approaches of the model, there are problem-solving strategies, set up at three levels in the book. At the content organisation level, tutorial problems provide a context for learners to select relevant types of knowledge most desired in this situation. At the algorithmic procedure level, questions presented in the procedural steps motivate and guide students to *learn to think* by doing certain tasks. At the answer-solution level, the answers entered by students and the sample solutions provided give them the opportunity to evaluate their progress, thereby intensifying their awareness of the status of their own knowledge.

Problem-oriented context

The tutorial problems act as a learning guide for students to acquire and employ knowledge through the algorithmic structure. By analysing the problem situation, students identify and employ the conceptual and procedural knowledge in order to discover solutions in new situations. By analysing solutions or results, on the other hand, students need to identify the relationships between the concepts and principles and how they relate to the given problems, as well as how to verify the conceptual knowledge used. This assists them in making themselves aware of the important concepts and principles, or how to be critical in a given problem situation. Problem-oriented situations can greatly improve students' high-order cognitive abilities [5].

Algorithmic procedures

As mentioned earlier, one of the significant characteristics of the book is the design of a variety of algorithmic procedures. In the book, the structure of an algorithmic procedure typically consists of the description of a situation and performance objectives, followed by a step by step procedure. The questions employed in the procedure create a situation in which students are required to think *what* should be done in the process of acquiring procedural knowledge and *why*, by either solving the theoretical problems or experimenting in the laboratory. This implies that some cognitive strategies will be used by students in a natural way, meaning that students may not necessarily realise that they have been conditioned to perform these strategies. Obviously the cognitive strategies used by subject matter experts, such as *backward chaining* and *generalisation* etc, are embedded in the algorithmic procedures. By following the procedures, students gradually develop a correct way of thinking and doing, thereby developing the knowledge, skills and professional habits required for their future jobs.

Question-answer solutions

The *question-answer* solution strategy in the book requires students to write their answers freely by providing them with a blank space for recording their answers. The book also provides students with the opportunity to evaluate their achievements by giving sample solutions. This question-answer solution process is partially uncontrollable in the book, which means the order through which the students' expressions are recorded and presented relies heavily on their learning styles, confidence and responsibility. Obviously, students can cheat by copying the solutions provided, and they may obtain a high mark for their work. Of course if students want to cheat, they can cheat themselves of an education which in the future would warrant professional success. Although the assessment process appears not to be extremely reliable, the author has made a conscious decision to challenge the honesty of students. By taking advantage of hypermedia technology, free access to the sample solutions can be denied or controlled. It will be the personal choice of an individual lecturer to provide students with access to the solutions without penalising them for the occasional use.

In summary, the design of the material combines technical knowledge with modern educational psychology and instructional design. The integration of the strategies adopted in the procedures, such as the content type orientation, layer-nested sequencing and problem-solving algorithms, provides a reliable basis for achieving the educational goal. The experimental work carried out with the book has shown it to be a reasonable and effective tool for the primary undertaking of electrical engineering. According to a survey conducted in the School of Electrical Engineering at the University of Sydney, it was evaluated that the subject material satisfactorily covered the teaching programme, and that the adopted teaching philosophy, the book design and the way in which the problems were presented were effective and satisfactory [3].

CONCLUSION

The role of content analysis is to provide a reliable theoretical foundation and the basic prerequisites for choosing or designing subject content material suitable for the development of a hypermedia-assisted learning system.

Obviously, the effectiveness of content analysis can be greatly promoted by employing relevant theories as underpinning. In principle, any learning or instructional theories can be adopted in the analysis. The key point is how to choose and combine the theories to achieve effectiveness.

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BIBLIOGRAPHY

Ms Shi Tao graduated from the XinJiang University, Urumuqi, China, with a Bachelor of Radio Engineering in 1979. From 1979 to 1993 she was a lecturer in the XinJiang Normal University, Uru-muqi, China. Presently she is a Master's student within the UNESCO International Centre for Engineering Education, Monash University, Melbourne, Australia.

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He received the inaugural AAEE Medal for Distinguished Contributions to Engineering Education (Australasia) in 1991 and was awarded the Order of the Egyptian Syndicate of Engineers for Contributions to the Development of Engineering Education on both National and International Levels in 1994. In June 1996, Professor Pudlowski received an honorary doctorate from the Donetsk State Technical University in the Ukraine in recognition of his contributions to international engineering education, and in July 1998 he was awarded an honorary Doctorate of Technology from Glasgow Caledonian University, Glasgow, Scotland, United Kingdom. In 1997, he was elected a member of the Ukrainian Academy of Engineering Sciences.