Design of a Knowledge Acquisition Tool using A Constructivist Approach for Creating Tailorable Patient Education Materials

by

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Abstract

Research in patient education suggests that tailored educational materials can improve patient's understanding of a treatment plan and help to achieve patient engagement and compliance. The goal of the HealthDoc Project has been the creation of automated Natural Language Generation systems for producing educational materials that are tailored to an individual patient's medical condition and personal situation. The project has so far focused on developing computational linguistic tools needed to author tailorable content from which customized versions could be generated. Also the HealthDoc model of document generation assumes the existence of previously authored textual material. Therefore, a new approach is needed to construct these materials and ensure that the relevant medical knowledge will be captured and delivered to the patient by providing a means to assist the health care professionals in directly authoring the required domain knowledge.

We have used constructivist educational theory and knowledge-level modelling to define a new approach incorporating Patient-centric and Behaviour-modifying Educational Model (PBEM) and a knowledge-acquisition framework. Unlike traditional approaches, in which all patients are treated alike in terms of the medical information provided, our new model takes into account characteristics of individual patients. This facilitates the patient's assimilation of relevant information pertaining to her behaviour and health. As the information provided must address the various concerns of different stakeholders, and different patients have different concerns and concern intensities, a knowledge-acquisition framework was developed to provide a structure for patient knowledge acquisition. This framework includes the following components: a Strategic Model, a Concerns Model, and an Interrogation-based knowledge-acquisition Tool. The tool is intended to be used directly by health care professionals and to assist them in formulating, structuring, representing, and articulating their domain knowledge. This research work explores a new field, knowledge-level modelling, for generating patient-tailored educational materials and provides guidelines to implementing such a knowledge-acquisition tool.

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Chapter 1

Introduction

Providing information to patients is a key component of gaining informed consent and achieving patient engagement during medical interventions. However, it is a challenge to ensure that the proper information about these interventions is communicated in advance.

Research in patient education [12, 22, 32, 33, 34, 57] suggests that tailored health educational materials can improve patients' understanding of their treatment plan and help to achieve patient engagement and compliance. The HealthDoc Project [18] at University of Waterloo proposed a new Natural Language Generation paradigm for generating texts that are tailored to an individual patient's medical condition and personal situation. The project has so far focused on developing computational linguistic tools and resources needed to author tailorable content from which customized versions could be generated. No work has been done, however, on how to acquire the proper knowledge for educational content and deliver it to the patient.

The purpose of this research is to create a new patient-education model and to develop a knowledge-level modelling approach for knowledge acquisition. This is done in order to create a discourse structure before the actual-text-content authoring of the educational materials.

Since one of the research objectives is changing patient behaviour, we reviewed education literature and discovered the concept of Constructivism [20, 23, 29, 56]. Constructivists assume that the learner constructs her own knowledge by combining her experience with the information provided by the educator. In order for the learner to understand and apply the knowledge, the educator must consider the individual learner's characteristics and experience. We apply constructivist theory to construct a Patient-centric and Behaviour-modifying Educational Model and to design a knowledge-level modelling framework. An Interrogation-based acquisition tool will implement the concept of the framework and be used directly by the health care professionals to articulate their domain knowledge. The knowledge constructed using this tool will create a discourse structure for tailored educational materials and assist health education writers in authoring the tailorable educational materials.

This chapter is an introduction to the research. Section 1.1 explores the motivation for this research work. Next, section 1.2 provides the background information of the HealthDoc Project and compares three authoring tools developed for HealthDoc. Section 1.3 states the problems not addressed by the HealthDoc Project and introduces our solution. Finally, section 1.4 outlines the structure of the remainder of this thesis.

1.1 Motivation for the Research

It is increasingly recognized that providing effective information to patients is a key step in gaining informed consent and achieving patient engagement [4, 15, 34]. Therefore, providing patients with effective education is an important issue in modern health care, particularly in medical or surgical interventions. However, it is a challenge to ensure that proper information about these interventions is communicated in advance.

Currently, patient education is largely provided through face-to-face verbal interaction with health care professionals [32]. Health care professionals not only respond to nonverbal signs from a patient, but also tailor the educational information to individual patients [19]. There are, however, some problems with this approach:

- Health care professionals have limited time. Thus, patients are more likely to receive only a small amount of educational information directly from their physicians [19].
- Many patients are nervous and forget what they are told by the clinician. A study by Kitching [34] found that, on average, patients forget half of what they were told by a doctor within five minutes of leaving the consultation room.
- Health care professionals sometimes bypass points which they may think are unimportant, and it is easy for them to get bored explaining the same information repeatedly [32].
- Health care professionals may overutilize ineffective education strategies, and underutilize more effective behavioural or psychological techniques [43].
- Patients may be too embarrassed to ask certain questions or too shy to ask the doctor to repeat something if they don't understand it [19].

Pre-printed brochures, videos, and other educational materials can supplement face-to-face interactions. There is no boredom factor, no pressure to speed up or slow down, and no accidental skipping of key points. This leaves the patient able to proceed with educating herself at her own pace, in private, and without placing demands on a health professional's time [12]. However, these materials are impersonal and nonspecific, and therefore may not address a patient's particular needs.

Tailored health educational materials, such as brochures and on-line information, attempt to combine the advantages of face-to-face communication with supplementary materials. They have been shown to have a significant effect on improving patients' understanding and retention [12, 32, 33, 34, 57]. This will be elaborated in a later section of this chapter.

The HealthDoc Project [18] proposed a general solution for generating tailored patient-education materials. However, its focus was on developing a new Natural Language Generation paradigm and designing authoring tools for use by computational linguists and technical writers. The issues which HealthDoc did not address include how to acquire the domain knowledge for creating the discourse structure of tailored educational materials without involving a knowledge engineer, and how to present and deliver such knowledge properly for the education of the individual patient.

In the following section, we will look in more detail at patient education and consider its importance, benefits, and challenges.

1.2 Patient Education

1.2.1 Definition

According to Van Den Borne [58], patient education is: "a systematic learning experience in which a combination of methods is generally used, such as the provision of information, advice and behaviour modification techniques, which influence the way the patient experiences her illness and her knowledge and health behaviour. This is aimed at improving health and learning to cope with a condition, usually a chronic one. Patient education may also involve influencing emotions and attitudes and is often aimed at altering behaviour."

Patient education can be defined as the process of influencing patient behaviour and producing the changes in knowledge and attitudes necessary to improve health.

1.2.2 Significance

As mentioned earlier, providing information to patients is a key step in gaining informed consent and engaging patients in their treatment. In some countries, such as Finland, laws exist that require health care providers to provide patients with information about their state of health, the significance of the medical care, various alternative forms of treatment and their effects, and other factors related to the patients' care [28]. In Canada, we are expecting a similar law to be introduced.

Information itself does not change behaviour, but if it is presented in an appropriate way, it can motivate the patient to be more actively involved in her own treatment and perhaps achieve the purpose of modifying behaviour.

Informed Consent

Informed consent is the process of attaining a patient's permission to allow a health professional to perform a treatment on that patient. It involves two fundamental steps:

- Giving the patient relevant information, as defined in Section 1.2.1,
- Obtaining the patient's agreement to proceed, given the patient's consideration of this information.

Informed consent is not merely getting a written consent signed by the patient and a witness. It must ensure that the patient understands the nature of the procedure, the risks involved, and the possible outcomes. Informed patients are better aware of matters related to their care, and are more likely to become active partners in the management of their own health. [14, 47, 58]

Patient Engagement

Patient engagement is another important goal of patient education [14, 15]. In addition to understanding her health status and treatment options, the patient also needs to follow the health care professionals' advice to alter ingrained habits, lifestyle and other elements of daily life, such as eating, drinking, sleeping, and recreation.

Patient engagement and informed consent support each other. Informed consent includes being open about the risks and uncertainties of the intervention. Openness promotes honesty between the patient and the health professional and makes for better doctor-patient relationships. The consequence of this is that the patient is more likely to achieve engagement and to be actively involved in the treatment [14].

Benefits

Patient education can provide substantial benefits for both the health care professionals and the patient [12, 28, 32].

For the patient, these benefits include:

- Reduction of anxiety,
- Recognition of possible complications,
- Better tolerance of complications,
- Faster recovery and rehabilitation.

For the health professional, these benefits include:

- Reduction of length of stays at hospital,
- Reduction of post-intervention visits or time required in such visits,
- Reduction of medication needs,
- Enhancement of patient satisfaction,
- Reduction of hospital resource consumption.

1.2.3 The Challenge

In order to achieve the goals of informed consent and patient engagement, we need to ensure that appropriate information is communicated regarding the patient's intervention.

Health care interventions are becoming increasingly complex, often involving multi-step procedures with multiple health care professionals. For example, in breast reconstructive surgery, there are various surgical options and sub-options available, each with different advantages and disadvantages (See Figure 1.1). Given this reality, it becomes very difficult or impossible for a health professional to deliver all of the needed information to the patient through face-to-face communication and general supplementary materials.

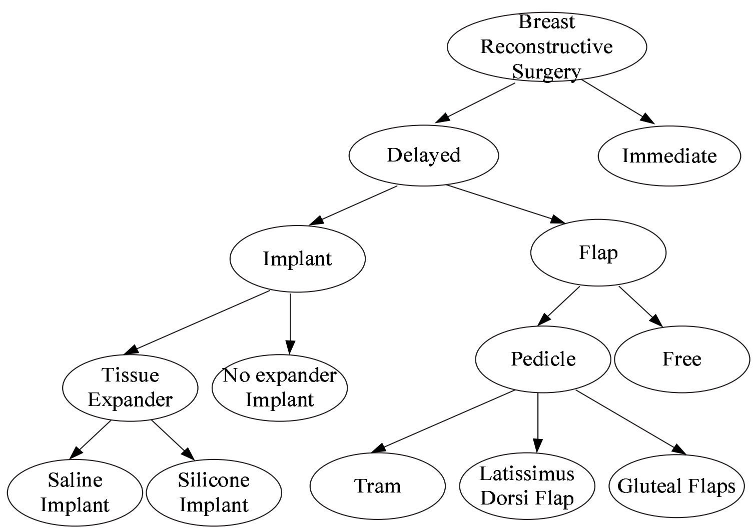

Figure 1.1: Breast Reconstructive Surgery Decision Tree (Partial)

1.2.4 Tailored Patient-education Materials

Tailored[1] health educational materials, such as brochures and on-line information, have been shown to have a significant effect on improving patients' understanding and retention [12, 32, 33, 34, 57]. For example, experiments in North Carolina [55] using customized smoking-cessation brochures produced a cessation rate of 20.8% which was 2.8 times the cessation rate of the control group (7.4%). Such materials are a valuable complement to face-to-face interaction.

Customizing information for the individual patient means providing the patient with the necessary information and excluding irrelevant information. It allows more intervention-specific detail than generic brochures, which attempt to satisfy all situations but usually fail to include specific information. Moreover, customization enables the 'tuning' of content to the level of readability, motivational style, and specific concerns of each patient. In the long term, tailored patient education may help to gain informed consent and achieve patient engagement more reliably than current methods.

1.3 Background

It has been recognized by researchers and health practitioners that patient-education materials cannot simply be 'thrown together' [12, 19, 25, 31, 32, 38, 57]. Rather they must be tailored to be pertinent to the individual patient. The result is that the patient is more likely to read all the material, to accept and internalize the information, and to follow the prescribed treatment.

There are several research projects working on generating personalized patient information, such as Migraine [10], Piglit [6], OPADE [11], STOP [49], and HealthDoc [18]. Various techniques have been used for tailoring, from Mail-Merge[2], to Schema-Based tech-

[1] In this thesis, unless otherwise noted, Tailored, Customized, and Personalized are synonymous.

[2] Mail-Merge technique: this involves inputting data into predefined slots in a template document.

niques[3], to more sophisticated Natural Language Generation techniques[4]. However, most of these techniques produce inflexible and awkward document structures and texts. Texts produced by these systems have exhibited limited variation in word choices, sentences and discourse structures, and virtually no variation in rhetorical and pragmatic expressions.

To address these limitations, the HealthDoc Project proposed a representation for a tailorable multimedia document [18] and a novel natural language approach capable fine-grained tailoring.

1.3.1 The HealthDoc Project

The HealthDoc Project developed a new Natural Language Generation paradigm for generating finely tailored documents, called generation-by-selection-and-repair. The HealthDoc approach is based on two primary components:

- The 'master document': a knowledge structure that contains all the information that might be needed to produce customized materials for many different users and from which a tailored document will be generated;
- The 'selection engine': a facility which selects text relevant to a particular patient from the master document, after which the selected text will be edited ('repaired') to remove syntactic or stylistic problems resulting from combining pieces of text.

As Figure 1.2[5] shows, a master-document specification begins with the top-level *Document* definition, expands into the intermediate levels of *Sections* and component *Topics*, then bottoms out into individual *Sentence* and *Lexical* items... A Document has an associated set of DocumentVariations, a Section has a set of SectionVariations, and so on.

[3]Schema-Based technique: this involves selection and organization of the content data according to simple document-template structures.

[4]Natural Language Generation technique: this involves generating natural language from a machine based representation, such as a knowledge base or a logical formalism.

[5]Chrysanne DiMarco, personal communication.

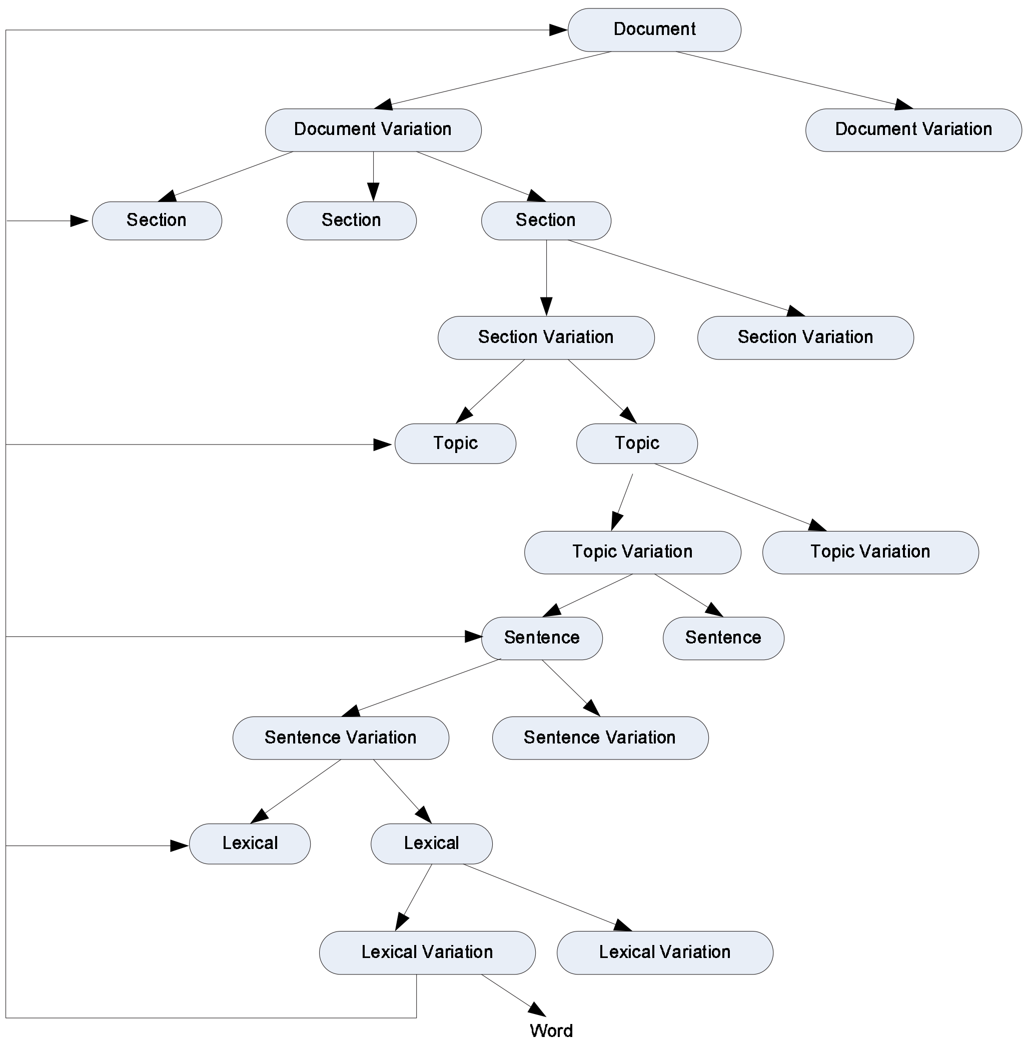

Figure 1.2: Master Document Structure

The current HealthDoc system for producing tailored documents starts from the pre-existing text snippets stored in the master document, selects the pieces of text relevant to a particular patient, combines these snippets into a customized document, and then edits (repairs) the resulting document to remove stylistic and syntactic infelicities. As a master document encapsulates all the variations on a given topic that might be needed for any reader, it represents the text at multiple levels of linguistic description, from surface text to deep-syntactic expression, and even semantic levels of representation. Figure 1.3 [45] shows the structure of the HealthDoc natural language generation system.

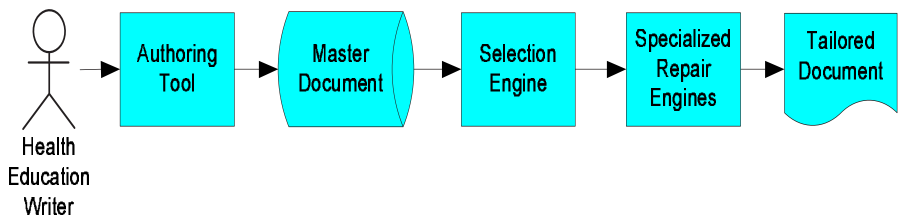

Figure 1.3: The HealthDoc Natural Language Generation System

This solution is more general than those used in previous systems, allowing not only the potential inclusion of text plans and schemas, text templates, and canned text, but also of very fine-grained revision and tailoring by a text-repair facility. This approach is capable of producing high-quality and stylistically expressive text.

The HealthDoc approach relied on pre-existing texts from which new text would be created. Three prototype authoring tools were developed to support the HealthDoc Project. They are intended to provide assistance in inputting text, that will then be stored in a master-document structure. Details will be given in the next section.

1.3.2 Authoring Tools for Natural Language Generation

An *authoring tool* is a software system that supports an author in creating and maintaining documents. It provides a method for specifying more than just the content of the document; it also assists the author in structuring the document and organizing the content.

Different natural language authoring approaches, addressing different levels of linguistic description, have been developed. One example is 'WYSIWYM' (What You See Is What

You Mean) [46]. It allows domain experts to encode their knowledge by interacting with the feedback text generated by the system, and viewing the knowledge defined so far. However, the document structure is based on an underlying knowledge model and the types of texts produced need to be standardized in organization and less expressive in style. Brun, Dymetman, and Lux [9] promote an XML authoring approach which uses a choice tree, other than the DTD, so that dependencies between substructures can be easily stated. According to this approach, the author can view the text in his own language and the document content is built in a language-independent representation, so the system could build several multilingual texts simultaneously. However, none of these authoring approaches provides a general solution; each can only be used in certain situations.

The HealthDoc Project developed its own authoring tools in order to construct tailorable documents from which customized versions could then be produced. These tools provide facilities for creating the master document, specifying the conditions for which each piece of text is relevant, and specifying rhetorical, coreferential, and ordering relations among pieces of text. During the development of the HealthDoc Project, three authoring tools were developed for different levels of linguistic representation: one supporting authoring of the deep-linguistic form, one supporting authoring of surface text, and one supporting the translation of surface text to deep-linguistic form.

SPLAT: A Sentence Plan Authoring Tool

SPLAT [27] is an authoring tool designed in an early stage of the HealthDoc Project. This tool provides authoring at the deep-syntactic level. Using SPLAT, the author first defines elementary linguistic components: qualities, objects, processes, and relations, then uses these as 'building blocks' to describe increasingly larger pieces of the sentence, until a complete 'Sentence Plan Language' (SPL)[6] [30] expression for the entire sentence has been constructed.

[6]Sentence Plan Language gives a deep-syntactic representation of a text.

However, SPLAT requires users to have explicit knowledge of deep-syntactic representation in the form of SPL expressions. Its intended users are linguists or computational linguists who would be familiar with the details of grammatical representations and capable of understanding the types of discourse and rhetorical labels used in SPL.

Authoring of Surface Text

As SPLAT requires the user to be a linguistic expert, another authoring tool was developed for professional technical writers, rather than linguists, to enter text at the surface level. This authoring tool, developed by Parsons [45], allows the author to enter variations of each piece of the document and to specify conditions for selecting a particular variation. It also permits the author to specify the rhetorical relations between pieces of text and to indicate words and phrases that are coreferential. It assists in constructing and editing the master document by enabling the author to define snippets of text and to mark them up with linguistic and semantic information for later re-use. With this tool, labelled text components can be defined for later re-use in multiple documents, and the linguistic information entered can be used to repair the syntactic or stylistic problems caused by the combination of selected pieces of text.

Although this authoring tool could be used to author documents on any topic (not only patient education), it is rare to find an author who has both domain and linguistic expertise.

ESTUSS: English to SPL Translation Using Stylistic Subsumption

ESTUSS [3] was developed to assist in the authoring of master documents at multiple levels of linguistic description by automating the transformation of surface text to deep-syntactic representation. Since SPLAT's main difficulty was in matching an entire sentence to a single template, the ESTUSS approach is to split a sentence into manageable components, classify them, determine the SPL templates for these basic components, and then rebuild the SPL expression of the overall sentence while constructing a larger and larger SPL statement. ESTUSS assembles existing linguistic resources, such as a syntactic parser (PUNDIT [16]), a stylistic parser (ASSET [26]), and a knowledge representation language (LOOM [8]) to implement its methodology.

ESTUSS attempted to achieve the benefits of the previous two levels of authoring. However, some features in previous two tools have been lost from the new tool, such as specifying sets of variation for the master document and the related rhetorical and other linguistic relations.

1.4 Problem Statement

As detailed in the earlier analysis of the project and its authoring tools, previous work on HealthDoc has so far focused on developing computational linguistic tools for actual-text-content authoring. However, as an approach suitable for providing patient education, nothing has yet been addressed about how to deliver the right information to the patient and how to provide the required domain knowledge to create the discourse structure of tailored educational materials for the master document.

Generating tailored educational materials is neither the beginning nor the end of effective patient education. We need to ensure that the required domain knowledge is expressed in the text and that the text effectively delivers information to the patient. This is done so that the text is accepted and internalized. These materials help the patient achieve an understanding of her illness, obtain sufficient knowledge to make good decisions, and have the ability to participate in her treatment process.

The following list indicates the problems that need to be addressed in our research:

- Much of the current tailored educational material claims to be patient-centric, but is still written solely from the health care professional's point of view, and does not satisfy the patient's actual information needs;

- Educational materials have been generally used as the means for transferring purely factual information to the patient. However, our objective is to provide knowledge that goes beyond strictly factual and is more useful to the patient;
- It is a difficult and time-consuming process for health education writers to understand both the domain knowledge and the patient-education challenges that must be addressed.
- A tool is needed to create the discourse structure of tailored educational materials before health education writers begin the actual-text-content authoring.

It is necessary to develop a new education model to express the actual situation of patient education. There is also a need for a knowledge-acquisition tool to assist health care professionals in formulating, structuring, representing, and articulating their domain knowledge.

1.5 Thesis Outline

In this thesis, the following components will be explored to address the above mentioned challenges:

- A Constructivism-based patient-education model.
- A Constructivism-based knowledge-level modelling approach.
- A knowledge-acquisition tool based on Interrogation.

In Chapter 1, we discussed the motivation for our research by introducing the importance and challenges of patient education and the creation of tailorable educational materials. By reviewing the HealthDoc Project and its authoring tools, we examined their limitations and briefly presented our new approach.

Following this, Chapter 2 introduces an epistemological approach to patient education: Constructivism. We analyze the traditional approach to patient education and the current reality of patient education. A new Patient-centric and Behaviour-modifying Educational Model is proposed.

We describe, in Chapter 3, relevant background in the area of knowledge acquisition by introducing the basic concepts involved, and by comparing two knowledge-acquisition paradigms: mining from the expert and knowledge-level modelling. We will also survey three typical knowledge-level modelling methodologies.

Chapter 4 illustrates our own Constructivism-based knowledge-acquisition framework for creating tailored patient-education materials, which includes the following components: knowledge-level models for patient education, Interrogation for knowledge acquisition, and a knowledge-acquisition tool.

Then in Chapter 5, we present a case study in the area of breast reconstructive surgery to demonstrate the viability of our framework.

Finally, Chapter 6 summarizes our research contributions and gives suggestions for future work.

Chapter 2

Constructivism-based Patient Education

2.1 Introduction

As introduced in Chapter 1, patient education is an important issue for both healthcare professionals and patients. However, patient education has long been regarded as a simple knowledge transferral process: healthcare professionals provide factual information to their patients and the patients are passive recipients.

Typically, patient participation is impaired by concern about the upcoming medical intervention. Patients have varying concerns and anxiety levels regarding their disease and treatment. The traditional patient-education approach could not properly represent this situation. Therefore, we need to define a reasonable educational model such that it addresses the characteristics of individual patients. It also needs to facilitate each patient's assimilation of the knowledge relevant to changing her behaviour and acting to improve her own health.

In this chapter, we first introduce constructivist theory, then analyze the traditional approach to patient education. A new Constructivism-based model is then introduced: Patient-centric and Behaviour-modifying Educational Model.

2.2 Constructivism: an Epistemological Approach

2.2.1 Introduction

The goals of education are to increase the ability of learners to differentiate between types of knowledge, to acquire new knowledge, to communicate knowledge, and to acquire skills for use in real-life situations [29]. Since the late 1800s, there have been three basic epistemological approaches to education: Behaviourism, Cognitivism, and Constructivism. However, Behaviourism and Cognitivism are both teacher-centric in nature. Constructivism is the only approach, of the three, which promotes a learner-centric experience.

The basic concept in Constructivism is that knowledge is constructed internally by each individual. Behaviourism views knowledge as something that happens in response to external factors. Cognitivism regards knowledge as abstract symbolic representations inside the learner's head. In the case of the constructivist view, each individual shapes knowledge to fit within her frame of reference, therefore no knowledge is transferred intact between individuals. [20]

2.2.2 Constructivist Theory

Constructivism is a theory about knowledge and learning. The theory states that the educator is only the knowledge provider, and that the learner constructs her own knowledge from experience. This theory is based on the work of Jean Piaget and Lev Vygotsky [23].

Fosnot [23] (p.ix) has provided an inclusive definition of Constructivism: "Learning from this perspective is viewed as a self-regulatory process of struggling with the conflict between existing personal models of the world and discrepant new insights, constructing new representations and models of reality as a human meaning-making venture with culturally developed tools and symbols, and further negotiating such meaning through cooperative social activity, discourse, and debate."

The constructivist believes that "learners construct their own reality or at least interpret it based upon their perceptions of experiences, so an individual's knowledge is a function of one's prior experiences, mental structures, and beliefs that are used to interpret objects and events." [29]. Because the learner is able to interpret multiple realities, she is better able to deal with real-life situations. If a learner can solve a problem, she can then better apply her existing knowledge to subsequent, related, situations.

According to Constructivism, meaning and knowledge are constructed by learners actively interpreting their experiences. Teachers should be facilitators for knowledge construction, rather than transmitters of knowledge. "Too often teaching strategies and procedures simply assume that what teachers perceive and infer from their perceptions is there, ready-made, for the students to pick up. However, teachers who base their practice on Constructivism reject the notions that meaning can be passed on to learners via symbols or transmission, that learners can incorporate exact copies of the teachers' understanding for their own use, that whole concepts can be broken into discrete sub-skills, and that concepts can be taught out of context." Therefore, learning is a constructive activity that the learners themselves have to carry out. In other word, knowledge can be used differently by various individuals and each of them has to build up knowledge for herself. [29]

The objective of constructivist education is to give the learner the knowledge and skills needed to do something. Therefore, with this approach, the learner is an active participant instead of a passive recipient in the learning process. For example, if guided by constructivist theory, after a 'Data Modelling' course, a student will not only understand different data models and structures, but will also be able to build a data model for a given scenario and represent it using a data structure.

2.2.3 Constructivist Model

Because knowledge is the result of the interaction between the learner and the environment, education becomes the process to facilitate the building of the learner's internal models, or representations, of external structures. The teacher helps the learner apply these structures and knowledge in real practice.

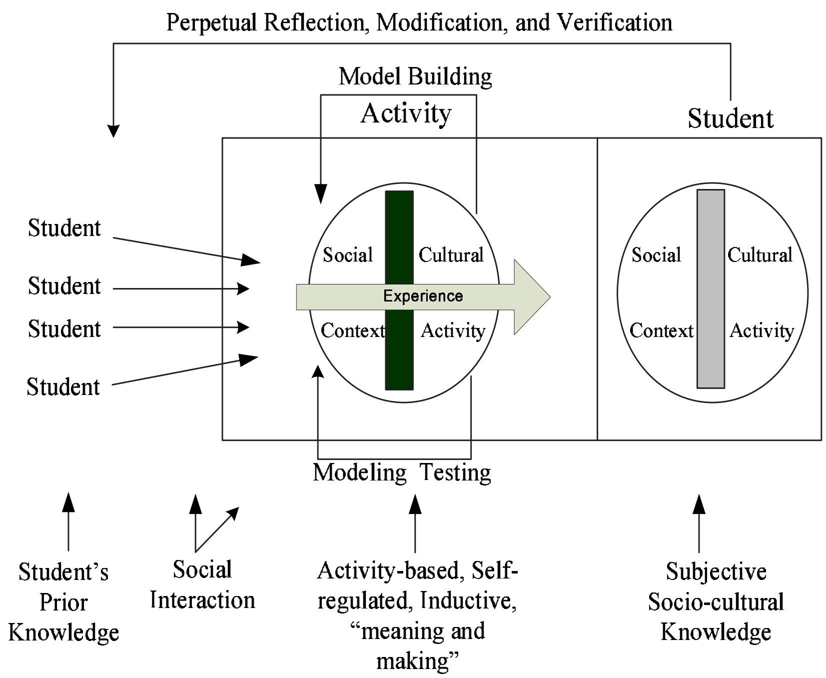

Figure 2.1: A Constructivism Model

Figure 2.1 [20] (p.5) is a Constructivist model expressly demonstrating the students' interaction with knowledge (represented by the dark rectangle in the figure) within a socio-cultural environment. The figure shows that the students' internal mental structures (models) are influenced by the presence of social, cultural, contextual, and activity-based factors. Therefore, the students do not acquire an exact representation of the knowledge (light rectangle in the figure), but rather a personal interpretation of the external knowledge. The accuracy of this constructed knowledge will be based on the student's prior knowledge and the impact of the social, cultural, contextual, and activity-based factors.

From the detailed explanation of constructivist theory given above, we can see that Constructivism is learner-centric and behaviour-modifying. By applying this theory to patient education, we propose a new Patient-centric and Behaviour-modifying Educational Model (PBEM) and use it to support our knowledge-level modelling approach.

Before we design our new patient-education model, we first examine the traditional patient-education approach and identify the mismatch between this approach and the demands of patient education.

2.3 Traditional Patient-education Approach

The Latin origin of 'doctor', *'docere'*, means 'to teach'. This implies that doctors are responsible for the education of patients regarding their health conditions, treatment, recovery, and similar matters.

The purpose of patient education is to empower patients, by means of education, to give them adequate information about their own care, and to help them manage their own health. Generally, patients need information about:their illnesses and treatments, side effects and complications, other health-related issues, and further care. Additionally, information is required concerning daily activities, practical solutions, and financial matters. Patient education needs to be effective in terms of both its content and methods.

A key question that needs to be answered is: who has control of a patient's education situation, the health professional or the patient? Obviously, the patient should be in control, but too often health care professionals try to control the situation for the patient, subtly threatening removal of support or services if she does not follow instructions. For too long, health care professionals, especially physicians, have been viewed as authority figures whose will must always be obeyed.[47]

Because of this, patient education has been regarded simply as a knowledge transmission process. According to this view, the information provided to a patient is determined by health care professionals. This means that health care professionals transfer what *they* think is important, mostly factual information. The patient is expected to mechanically ingest and passively accept the knowledge. Seen this way, health care professionals focus on information transmission, rather than information reception and assimilation. Figure 2.2 shows a simple model of this approach.

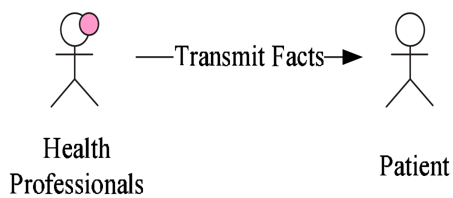

Figure 2.2: Traditional patient-education Model

2.4 The Actual Situation of Patient Education

Frequently, an individual patient selectively seeks help regarding symptoms that she is experiencing and looks for relevant information for dealing with them. This means that the patient enters into an educational process with a specific problem which causes her concern. For example, a patient facing breast reconstruction might worry about losing her breast and having a permanent scar. This worry may prevent the patient from actively participating in the intervention process. One of the goals of patient education is to minimize such blocks and help the patient become engaged in the treatment process.

It is clear that patient education involves much more than the simple transmission of medical information by the health care professionals to the patient using a vocabulary that the patient can understand [47]. It is also clear that merely increasing information does not necessarily ensure the patient's cooperation in medical treatment programs [53].

For the purpose of explaining our thinking, a patient can be considered as if she is composed of two parts: mind and body (See Figure 2.3). The body can go forward to the medical intervention with a minimum of consent, but the patient may have a 'mental block', such as worry about pain or disfigurement, which impairs her from fully participating in the intervention process. If the mind is not engaged, the patient's participation in, and compliance with, the intervention will be minimal. We can use Figure 2.4 to demonstrate this situation.

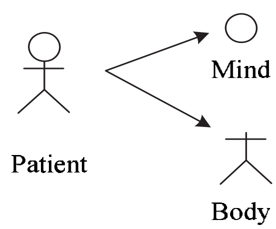

Figure 2.3: Patient's Two Parts: Mind and Body

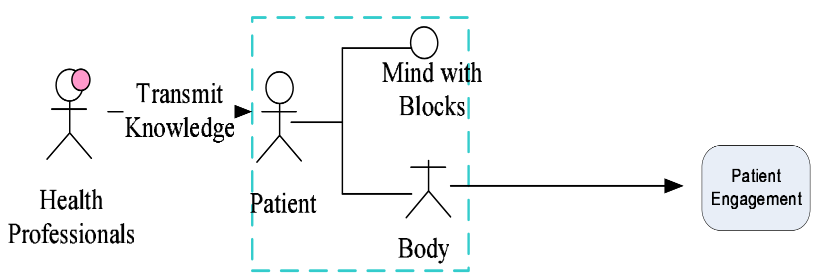

Figure 2.4: Actual Situation of Patient Education

If we take into account the real-life demands of patient education, and the problems of the traditional approach to patient education, it becomes clear that we require a new approach that can match a real situation to patient education and find ways to guide the design of patient-education materials. A new Patient-centric and Behaviour-modifying Educational Model, based on Constructivism, will be introduced in next section to fulfil these requirements.

2.5 Constructivism-based Patient-centric and Behaviour-modifying Educational Model

As presented in Chapter 1, the objectives of patient education are gaining informed consent and achieving patient engagement during the treatment process. Often however, the actual situation is that patients feel obsessed because their participation is impaired by worry about the upcoming medical intervention. Moreover, the traditional patient-education model can not properly address this real-life situation.

Constructivist theory appears to promise a good solution to the above problems. According to constructivist theory, knowledge is constructed by the individual learner based on her specific situation: the learner connects new information to already established knowledge structures and constructs new relationships among those structures instead of simply adding new information to the store of knowledge.

If we accept constructivist educational theory and apply it to our patient-education process, we will satisfy the practical needs of the patient, enabling her to take action for her own health, and also achieve the health care professionals' goal of ensuring effective treatment.

Accordingly, an effective model of patient education should be both Patient-centric and Behaviour-modifying.

2.5.1 Patient-centric Education

Patient-centric education demands the customization of educational materials. As mentioned in Chapter 1, simply customizing materials with the patient's demographic information, personal characteristics, or health conditions makes the materials more pertinent to the patient. This customization approach can also allow the removal of irrelevant information and keep only what is required by the specific patient.

However, in order to achieve Patient-centric education, customization alone is not sufficient, as most of the materials are still written from the health care professionals' point of view. Moreover, previous customization approaches assume there are already existing discourse structure of the actual-text-content and did not consider how to acquire and tune the materials to patients' various concerns and anxiety levels. Therefore, we need to completely shift the emphasis in patient education from the needs of the health care professionals to the needs of the patients. The patient's role as a learner should be carefully considered during the knowledge-building process for authoring educational materials. Patient-education materials should convey the appropriate information to the patient for addressing specific concerns as well as enabling the patient to take action for her own health.

2.5.2 Behaviour-modifying Education

In Behaviour-modifying education, the learner is not a passive information receiver. Individually tailored information helps the patient construct her own knowledge and apply this knowledge to the challenge of dealing with the medical intervention. As a result, the patient's concerns may be alleviated, 'mental blocks' may be removed, and she may become more engaged in the treatment process. Figure 2.5 shows the resulting Constructivism-based patient-education process.

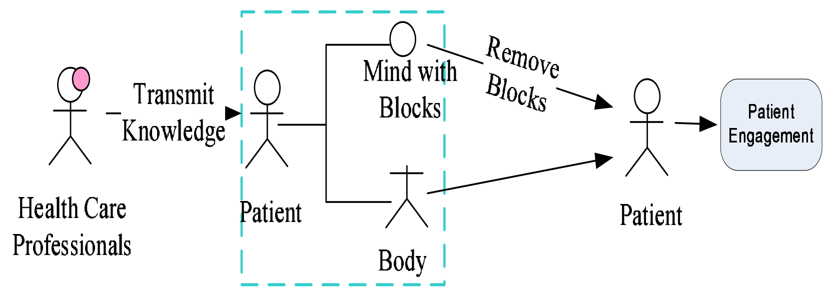

Figure 2.5: Constructivist patient-education Process

Thus, patient education becomes more than merely providing information to the patient. It involves influencing the patient's emotions and attitude as well as altering her behaviours that relate to the treatment. For example, we want to put the patient's mind at ease before surgery so that she will be less anxious and be able to participate appropriately in the treatment process.

We also need to recognize that the outcome of medical treatment is a multi-dimensional and subjective matter. The patient's view is highly relevant and significant [58]. The patient not only accepts knowledge, but also applies it to understanding the treatment and to altering her behaviour. When the patient understands her own health situation, and the treatment proposed, she takes ownership of the problems and uses the new knowledge to participate in the intervention process, comply with treatment, and moderate her concerns. By helping the patient in constructing her own knowledge and applying it, patient education influences the way the patient experiences the health-care process and engages the patient in her own care and treatment.

2.6 Summary

This chapter proposes a new Patient-centric and Behaviour-modifying Educational Model based on Constructivism. This model will be used to guide the design of patient-education materials and the application of these materials in educational situations. The constructivist theory introduced in this chapter will become the foundation for our research, not only our approach to patient education, but also our approach to knowledge acquisition.

In the next chapter, we will examine the background of knowledge-level modelling to prepare for the design of our Constructivism-based knowledge-acquisition framework.

Chapter 3

Knowledge-level Modelling

3.1 Introduction

As mentioned in Chapter 1, the HealthDoc Project and similar projects for generating tailored patient-education materials focus on linguistic description at various levels. In Chapter 2, we proposed a Patient-centric and Behaviour-modifying Educational Model for patient education. However, the issues regarding how to acquire domain knowledge directly from health care professionals and how to shape the knowledge to carry out the goals of the medical intervention have not been addressed.

This chapter gives background information on knowledge acquisition by clarifying terminologies and comparing two different paradigms: Mining from the Expert and Knowledge-level Modelling. At the end of this chapter, three typical knowledge-level modelling methodologies (CommonKADS, Mike, and Protégé) will be reviewed and summarized to provide useful information for our knowledge acquisition framework related to patient education.

3.2 Basic Concepts

3.2.1 Data, Information, Knowledge, and Intelligence

Before we talk about knowledge-level modelling, we need to clarify some terms: *data*, *information*, *knowledge*, and *intelligence*. These terms are often used in the field of knowledge management (KM) or knowledge engineering (KE).

The following diagram [5] represents the transitions of data to information to knowledge and finally to intelligence. It is human understanding that allows the transition from each stage to the next.

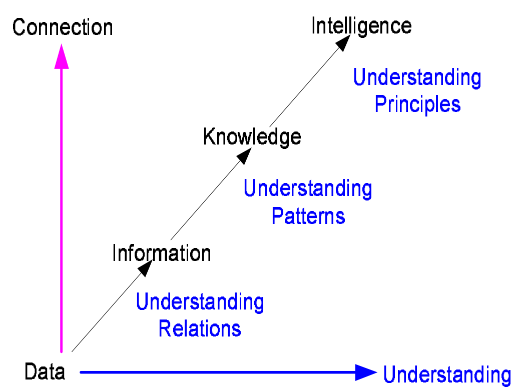

Figure 3.1: Relation of Data, Information, Knowledge, and Intelligence

Data

Data are the raw materials that have not been interpreted, such as numbers, words, images, symbols, etc. Datum, as the singular form of data, is regarded as the value of a specific parameter for a particular object at a given point in time [1]. A single piece of textual data, such as 'literacy level', has no meaning unless the context is specified. Data needs to be transformed to information to be understood.

Information

Information consists of facts and data that are organized in some way to describe a particular situation or condition [52]. Data have been given meaning by relational connections. For example, the fact that "patients have different literacy levels" is a piece of information where 'patient' and 'literacy level' are connected.

Knowledge

Knowledge consists of truths and beliefs, perspectives and concepts, judgements and expectations, methodologies and know-how [60]. It is derived through the analysis of data and information, and is a complex network of information [1]. The intent of knowledge is to be useful and meaningful. One of the characteristics of knowledge is to explain how to understand other pieces of information. For example, "patient's low literacy level requires educational materials in a more readable format" is a piece of knowledge. Knowledge depends very much on context.

Knowledge always has a purpose and is used to achieve a goal. A piece of domain description can be used for many different problems, and a problem-solving strategy can be used across a number of domains. However, knowledge is not easily captured, collected, represented, organized, processed, or transferred.

Intelligence

Intelligence is a general mental capability that includes: reasoning, planning, solving problems, thinking abstractly, comprehending ideas and language, and learning [61]. In Computer Science, it is generally related with Artificial Intelligence (AI).

In patient education, educational materials convey high-level knowledge instead of low-level data or information. The knowledge will be connected by the patient with her previous knowledge structure to remove mental blocks and achieve engagement in the treatment.

Our next step for this research is to develop a knowledge-level modelling approach and design a knowledge acquisition tool related to patient education. These approaches will assist health care professionals in articulating the domain knowledge which will be used for creating a discourse structure of the tailored materials.

3.2.2 Knowledge Level Versus Symbol Level

The distinction between knowledge and symbol levels was first introduced by Newell [40]. They represent two different levels of a computer program, especially a Knowledge-Based System (KBS)[1].

The knowledge level is developed to simply view the nature of knowledge or the aspect of knowledge and representation of concern. A system at the knowledge level is considered as an agent, and its components include goals and actions. The agent undertakes actions, based on knowledge it possesses, in order to reach a specific goal. "To treat a system at the knowledge level is to treat it as having some knowledge and some goals, and believe it will do whatever is within its power to attain its goals, in so far as its knowledge indicates." [40] (p.98)

Beneath the knowledge level resides the symbol level. Whereas the knowledge level is world-oriented, concerned with the environment in which the agent operates, the symbol level is system-oriented, including the mechanisms the agent has available for its operation. For example, in a computer program, the knowledge level consists of the information contained in its data structures. The symbol level consists of the program's algorithms, and the data structures themselves. At the knowledge level, we need to specify what the agent knows and what its goals are. A logical abstraction separates this level from details of implementation [40].

[1] A Knowledge-Based System is a computer program which incorporates knowledge about a domain to solve a task.

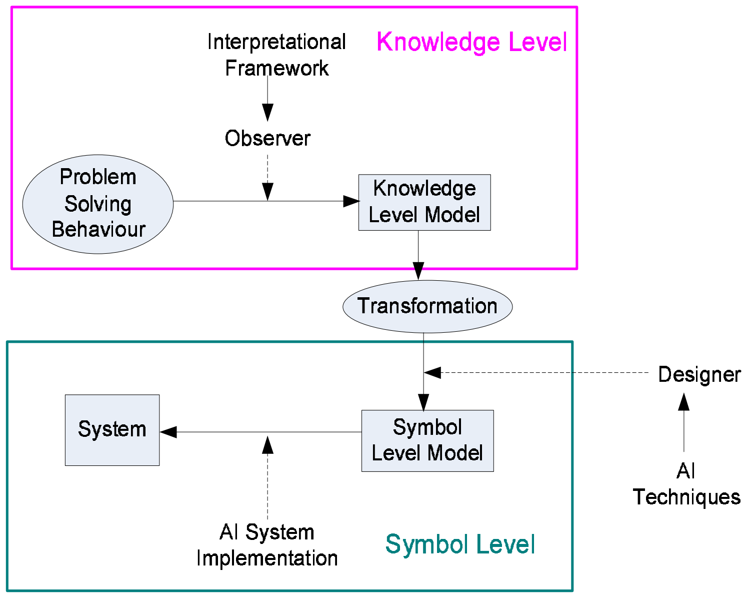

Figure 3.2: Structure of Knowledge Level and Symbol Level

Figure 3.2 [50] (p.16) provides a graphical representation of the knowledge and symbol levels in the development of a Knowledge Based System. The symbol level model is constructed by transforming the knowledge-level descriptions. This is done by selection of appropriate Artificial Intelligence techniques and representations, which are used to realize the specific problem-solving behaviour. Unified Modelling Language (UML) [7] can be used to design the knowledge-level model as well as to transform the knowledge-level description into the symbol-level description.

Menzies [36] and Newell [40] observed that knowledge engineering has put too much focus on detailed representational issues. Here, representation refers to the actual data structures and processes in a program. What was missing from previous knowledge engineering work was the description of the rationality[2] behind the representation. Knowledge-level

[2]Principle of Rationality: If an agent has knowledge that one of its actions will lead to one of its goals, then the agent will select that action. [40]

hypotheses lead to a shift of emphasis from the ‘how’ questions to the ‘why’ questions. For example, in knowledge level, why the system performs a particular action will be addressed instead of how to perform that action. The knowledge level is independent of its symbolic representation in terms of rules, frames, or logic, and provides a platform for studying knowledge independent of its representation in a programming language.

At the knowledge level, the behaviour of the system is described in terms of agents, goals, and actions. Put another way, the knowledge level characterizes the behaviour of problem-solving agents. With knowledge serving as the medium, an agent will carry out an action if it has the required knowledge and if one of its goals can be achieved by that action. The hypothesis of Newell also states that the knowledge level is implemented directly by the symbol level. Knowledge-level entities are represented by particular symbol-level structures, with each symbol structure having a coherent interpretation at the knowledge level [40].

The concept of a knowledge level has promoted the evolution of knowledge acquisition from ‘Mining from the Expert’ to ‘Knowledge-level Modelling’. We expand upon this description in the next section.

3.3 Knowledge-acquisition Paradigms

Knowledge Acquisition (KA) can be regarded as a method by which a knowledge engineer obtains information from experts, text books, technical manuals, research papers, and other authoritative resources for translation into a knowledge base understandable by both machines and humans [35].

During the evolution of knowledge engineering, two different paradigms have been developed, from ‘Mining from the Expert’ to ‘Knowledge-level Modelling’.

3.3.1 Mining from the Expert

In the initial phase of knowledge engineering, knowledge is transferred from experts then transformed into a representation formalism. This 'Mining from the Expert' paradigm assumes that expertise consists of a set of rules and that knowledge can be elicited fact-by-fact from domain experts, then encoded in computer systems.

MYCIN [39], a typical, rule-based system based on this paradigm, is an expert system developed at Stanford University in the 1970s to diagnose and recommend treatment for certain blood infections. Such systems provide a generic inference engine and rule-editing facilities to support the expression of knowledge as inference rules. This view of knowledge acquisition is still applied in some expert systems.

The mining approach considers an expert's knowledge and a rule-based representation as essentially equivalent. However, the mapping between the verbally provided expertise and the implementation formalisms is not a simple, one-to-one relationship. Schreiber [50] (p. 21) summarized the problems with this approach:

- The mapping from elicited expertise-data onto the required representation is difficult and often not possible;
- Systems with a large knowledge base become difficult to maintain;
- Explanation facilities are poor.

The main reason for these problems is that the gap between the observed problem-solving behaviour and the target application is just too wide. The system development process is often hindered by difficulties eliciting knowledge from experts and coding it into the system. Therefore, mining from experts can fail to capture important conceptual distinctions in the acquired knowledge. The system should not be analyzed in terms of its rule-based behaviour but in terms of the knowledge types it uses and conceptual tasks it carries out [17, 37].

3.3.2 Knowledge-level Modelling

Today, knowledge engineering is viewed as an approach to modelling activities [21]. As illustrated in the previous section, Newell [40] recognized the existence of a knowledge level in computer systems which describes conceptual knowledge and is separated from the symbol level of the description. Subsequently, knowledge engineering has shifted its emphasis from coding rules into a computer system to constructing different models of human knowledge from different aspects of domain problems.

Two approaches [54] have been identified for a knowledge-level description in knowledge acquisition:

- The first approach takes the implementation of a problem-solver as its starting point. Knowledge-level notions are introduced by providing abstract and implementation-free descriptions of the knowledge elements required by the problem-solver.

- In the second approach, the knowledge-level descriptions are part of a conceptual model of a task domain. The conceptual model serves as a specification of the knowledge requirements for a particular knowledge-based application. The conceptual model is not directly linked with the actual implementation.

Knowledge-level modelling concentrates on the conceptual structure of knowledge, and leaves the programming details for later. Knowledge-level modelling makes it possible to focus on *what* a system actually does, rather than *how*. This knowledge-level modelling approach has the advantage of separating problem-solving from implementation-related issues. Knowledge is then modelled at a conceptual level which will form an abstraction based on the data obtained from the expert.

According to this modelling paradigm, as shown in Figure 3.3 [50] (p.100), the development of a knowledge-based system consists of different types of activities :

- Knowledge-modelling activities aimed at constructing knowledge-level models of the application.
- Design and implementation activities aimed at applying a particular knowledge level model, through the selection and implementation of computational and representational techniques.

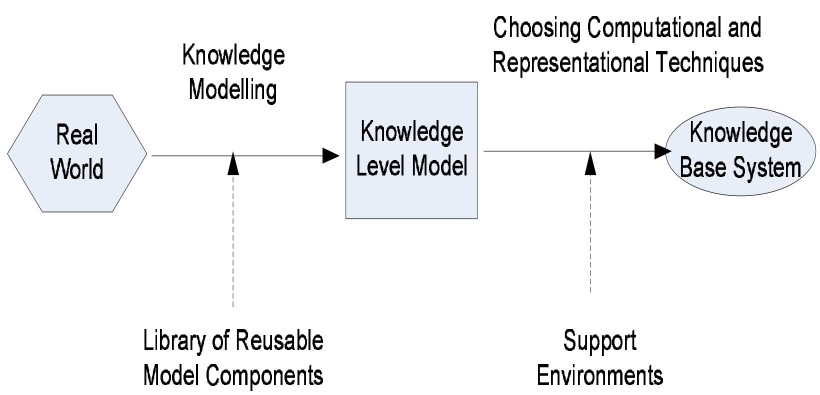

Figure 3.3: Knowledge-Based System Construction based on Knowledge-level Modelling

The essence of knowledge modelling is to represent a system at a level which is separated from implementation considerations and focus on the problem-solving. Knowledge modelling is a process for building a generic problem-solving model and acquiring the domain knowledge required to configure the problem-solving model.

It is important to note that knowledge-level modelling is not cognitive modelling, that is, simulating how experts think, nor a process of mapping experts' knowledge to a computational representation. Rather, it creates a model which offers results similar to a human's problem-solving approach. Knowledge acquisition becomes a knowledge-model construction process. Application-specific knowledge is organized according to the available problem-solving technology [37]. Knowledge-modelling activities can target a variety of domains, and can be performed in many contexts for a variety of purposes. These can be grouped as follows:

- Knowledge engineering: Abstract problem-solving and domain models can be developed prior to the implementation of the knowledge-based system. By specifying the knowledge and reasoning requirements of the prospective system, a knowledge-level model can be converted into a technical specification that is the basis for a software system implementation. A knowledge-based system is not a container filled with knowledge extracted from an expert, but an operational model that exhibits some desired behaviours that can be observed in terms of real-world phenomena.

- Knowledge management: A knowledge modelling approach can be used to develop a model of the competence of an organization, which will assist in decision-making or strategic planning. A core aspect of knowledge management is "getting the right knowledge to the right people at the right time in the right format."

- Knowledge sharing and reuse: A knowledge modelling approach can help to abstract components and make them reusable such that they can be configured for various applications.

Although knowledge modelling is developed mainly to support knowledge-based expert systems, such as a diagnosis or classification system, it can be used for other kinds of knowledge-intensive system applications.

Knowledge-level modelling acts as the starting point for understanding domain knowledge, and helps to identify the problems and find solutions. A knowledge modelling approach also makes it possible to characterize knowledge to handle complexity of the domain problems [17, 37].

This knowledge-level modelling has also been recognized as a constructive activity [21, 56, 59]. This is detailed in the next section.

3.4 Constructivism and Knowledge Acquisition

Constructivist theory was introduced in Chapter 2 as the theory behind the patient-education model. As described in the previous section, knowledge acquisition is through a knowledge-level modelling process rather than mining from the expert. This knowledge-level modelling has also been recognized as a constructive activity [21, 56, 59]. Constructivist theory is regarded as the foundation for using knowledge acquisition to achieve dynamic modelling.

Given the constructivist approach to knowledge acquisition, the experts and knowledge engineers collaborate in constructing explicit models for problem-solving in a specific domain. These external models are largely based on the expert's mental model of how to successfully solve problems. Thus the products emerging from the knowledge-acquisition process are essentially models created from models. These models are valuable because they can provide rich descriptions of the domain knowledge, independent of any particular implementation formalism. Furthermore, they can serve as a basis for communication between the experts and the knowledge engineers.

From a constructivist's perspective, a model is not a 'picture' of the problem, but rather a device for the formulation of knowledge about it. Indeed, sometimes the most important outcome of the modelling process may not be the model itself, but rather the insight we gain as we struggle to articulate, structure, critically evaluate, and accept the model. The value of a particular knowledge-acquisition effort is not simply due to a final, 'correct' representation of the problem, but also from our success in framing the activity as a self-correcting enterprise that can subject any part of the model to critical scrutiny, including our background assumptions. From this standpoint, the crucial question for knowledge engineers is not "How do we know the model is correct?", but rather "How useful is the model as a means of facilitating our understanding of the domain?". [21]

The next section will review three typical knowledge-modelling methodologies, CommonKADS, Mike, and Protégé, to examine whether they possess features that could be used in our new approach.

3.5 Knowledge Modelling Methodologies

When Newell [40] proposed the knowledge-level approach, no information was given about how to use knowledge-level modelling to build a knowledge-based system. Subsequently, different knowledge-modelling approaches have been developed, such as CommonKADS [51], MIKE [2], and Protégé [24]. We will review these three methodologies in this section by comparing the strengths and weakness of each.

3.5.1 CommonKADS

The CommonKADS [51] has been recognized as the best-established and the most comprehensive methodology among all current approaches to knowledge engineering. It has been gradually developed over two decades and has been validated by many companies and universities in the context of the European ESPRIT IT Programme. It is now the European standard for knowledge analysis and knowledge-intensive system development, and has been adopted by many major companies in Europe as well as in the U.S. and Japan.

CommonKADS provides a comprehensive framework in which both 'traditional' knowledge engineering projects and 'modern' knowledge management projects can be situated. The methodology is based on knowledge modelling and provides a suite of techniques to support knowledge analysis in an organization for a wide range of scenarios.

CommonKADS relies on defining a set of separate, but interactive, models to address the complexity of knowledge management:

- Organization model: The organization model supports the analysis of the major features of an organization, in order to discover problems and opportunities for knowledge systems, establish their feasibility, and assess the impact on the organization of the intended knowledge actions.

- Task model: Tasks are the relevant subparts of a business process. The task model analyzes the global task layout, its inputs and outputs, preconditions and performance criteria, as well as needed resources and competencies. This model defines what needs to be done.
- Agent model: Agents are executors of a task. This model specifies who does the task. An agent can be human, an information system, or any other entity capable of carrying out a task. The agent model describes the characteristics of agents, in particular their competencies, authority to act, and constraints. Furthermore, it details the communication links between agents carrying out a task.
- Knowledge model: This model defines the types of the knowledge required and gives an implementation-independent description of knowledge involved in a task.
- Communication model: This model describes the communication transactions between agents.
- Design model: This model defines the structure of the system that needs to be constructed.

Figure 3.4 [51] (p.18) presents the structure of the CommonKADS model set. The first level consists of the organization model, task model, and agent model. These analyze the organizational environment and the factors for success of a knowledge system; the second level, with the knowledge model and communication model, is the conceptual description of the problem-solving functions and knowledge that is to be delivered by the knowledge system; the artifact level is the design model, which converts the other models into a technical specification of the final, resulting implementation. This provides a template that can be configured, refined, and filled during project work. The number of models, and how elaborate they are, depend on the specific project context.

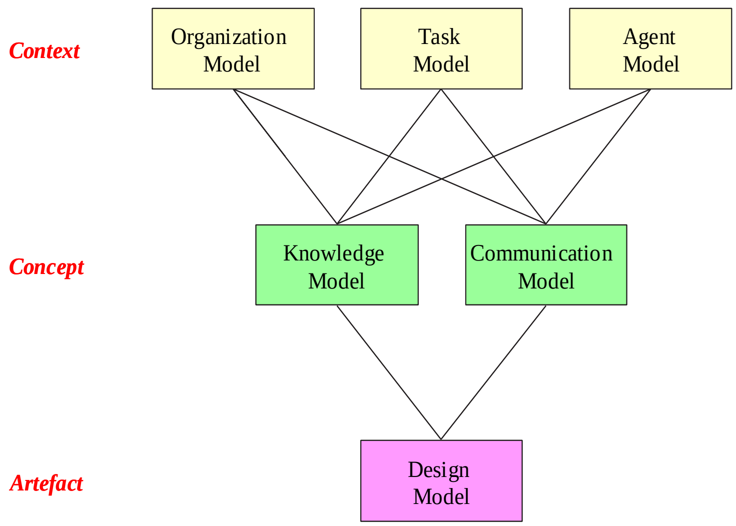

Figure 3.4: CommonKADS Model Set Structure

3.5.2 Mike

Mike (Model-based and Incremental Knowledge Engineering) [2] defines an engineering framework for eliciting, interpreting, formalizing, and implementing knowledge in order to build knowledge-based systems. It aims to integrate the advantage of life-cycle models, prototyping, and formal specification techniques into a coherent framework for the knowledge engineering process.

With Mike, it is assumed that the gap between the informal description of the knowledge and the final expert system is too big to be bridged by the expert, so the knowledge engineer works as a moderator in the modelling process.

According to Mike's methodology, there are three layers, each containing a special type of knowledge, in the knowledge acquisition phase of modelling expertise.

- Domain layer: This layer contains domain-specific knowledge about concepts, features, elements, and relationships. The objects and the terminologies of the domain are described so that the knowledge-based system can use them for problem-solving.
- Inference layer: This layer contains knowledge about the problem-solving method used. This layer indicates which inferences are necessary within the problem-solving method. The knowledge about the problem-solving method is both domain-independent and task-independent, and could be used in several domains and for different tasks.
- Task layer: This layer contains knowledge about the control flow of a problem-solving method that will be used to solve a specific task. It specifies the sequence of inferences. At the task layer a set of functions, a set of stored variables, and a set of Boolean variables are available.

There is also a ‘hyper’ model for the representation of knowledge at the conceptual level. This model consists of basic modelling components: nodes and links. Each node has a node-name, a node-content, a node-type, and an explanation-field. The link describes the relationship between two nodes, has direction, and includes a source-node, a destination-node, a link-name, a link-type, and an explanation-field. The ‘hyper’ model can be easily understood and used by the expert, who can then provide information with less assistance from the knowledge engineer.

One of the main features of the Mike approach is that the prototyping of the acquired expertise, using an executable model, is integrated into the modelling process.

We observe that Mike and CommonKADS use similar approaches, as example, the task layer of Mike is very similar to the task model of CommonKADS .

3.5.3 Protégé

Protégé [24] is a methodology for engineering knowledge-based systems that includes a supporting suite of general-purpose software tools. It has been developed by the Knowledge Modelling Group at Stanford Medical Informatics (SMI) Center. Protégé provides an extensible, platform-independent environment for generating and editing ontologies and knowledge bases.

There have been four generations of Protégé with the current version being Protégé-2000. It supports customized user-interface extensions and incorporates the Open Knowledge Base Connectivity (OKBC)[3] knowledge model, and interacts with standard storage formats such as relational databases, XML, and RDF. It has been used by hundreds of individuals and research groups, such as the "Foundational Model of Anatomy" project at the University of Washington and 'GALEN' at the University of Manchester.

A Protégé-2000 knowledge base includes the ontology and individual instances of classes with specific values for slots. The distinction between classes and instances is not absolute. The knowledge model of Protégé-2000 is compatible with OKBC, which is frame-based: frames are the principal building blocks of the knowledge base. A Protégé ontology consists of: classes, slots, facets, and axioms [41].

- Classes are concepts in the domain of discourse.
- Slots describe properties of classes.
- Facets describe properties of slots.
- Axioms specify additional constraints.

The knowledge model enables the interoperability between Protégé-2000 and other OKBC-compatible systems. The development of the knowledge model was influenced by

[3] Open Knowledge Base Connectivity [42] is an application programming interface for accessing knowledge bases stored in knowledge representation systems.

the requirements of structured knowledge acquisition. The Protégé-2000 metaclass architecture enables elegant and powerful knowledge modelling as well as allowing the knowledge engineer to implement the internal structure of Protégé-2000 explicitly in the ontology. The flexibility of the knowledge model and the component architecture of Protégé-2000 makes it easy to adapt as an editor for other knowledge-representation systems.

The fundamental features of this methodology throughout its evolution are as follows [24]:

- Knowledge-based systems should be designed for use by domain experts, rather than exclusively by knowledge engineers.

- Domain-specific knowledge-acquisition tools must be generated from an underlying domain model or ontology.

- During construction of these knowledge-acquisition tools, there is a division of labour between structural domain modelling and tool design, mostly carried out by the knowledge engineer, and filling in detailed domain knowledge, mostly carried out by the domain expert.

- Domain knowledge can be captured declaratively, without direct reference to an inference or problem-solving method. Conversely, inference methods can be isolated as problem-solving methods or as plug-in applications.

3.6 Summary

In this chapter, we analyzed two different knowledge-acquisition paradigms and concluded that knowledge-level modelling is the one that characterizes the problem-solving and knowledge construction. Knowledge-level modelling applies a constructivist approach.

Three different knowledge modelling methodologies have been reviewed in this chapter. This provides a reference for the design of our own approach to patient education.

Chapter 4

Constructivism-based Knowledge Acquisition for Patient Education

4.1 Introduction

This chapter will detail the development of a knowledge acquisition framework to address the requirements of patient education. In Chapter 2 and Chapter 3 we described constructivist theory as the theoretical foundation for both our patient-education approach and knowledge acquisition. In this chapter, we will combine the concepts of Patient-centric and Behaviour-modifying Educational Model with knowledge-level modelling to design a knowledge acquisition framework.

As detailed in Chapter 1, the HealthDoc Project up to now has focused on actual-text-content authoring at the symbol level and assumed a pre-defined library of educational materials, but it did not address how to acquire the appropriate domain knowledge and how to apply knowledge properly to patient education.

As an approach to solving these challenges, in Chapter 2 we proposed a Patient-centric and Behaviour-modifying Educational Model based on Constructivism. This supports patient education by concentrating on the patient's needs and the information required to empower the patient.

Now the problem that remains is how to elicit the knowledge from health care professionals and to provide it to the education writer. Our solution is to develop a knowledge acquisition framework. In this framework, knowledge-level models will be designed as the structures to contain patient-education knowledge, then a knowledge acquisition tool will be designed to assist health professionals in more easily constructing the models and articulating their knowledge. The acquired conceptual knowledge defines the discourse structure for tailored educational materials and provides information to facilitate health education writers in the actual-text-content authoring.

In Section 4.2, we will first describe our knowledge-level models for patient education. Then in Section 4.3 we will describe the concept of Interrogation and illustrate how to apply it to knowledge acquisition. Section 4.4 will specify the functional requirements to design a knowledge acquisition tool for patient education.

4.2 Knowledge-level Models for Patient Education

4.2.1 Introduction

As discussed in Chapter 3, knowledge-level modelling is the knowledge acquisition paradigm that simulates the human problem-solving process. Using this paradigm, experts and knowledge engineers can construct knowledge-level models for problem-solving. The knowledge-level models are the output of the knowledge-level modelling process. These models are first constructed by domain experts or knowledge engineers, then they are filled out by domain experts using domain knowledge.

In knowledge engineering, one challenge is to find an appropriate way of modelling knowledge schematically. We do not want to list all the possible pieces of knowledge in one large, flat knowledge base. This is much the same issue as having E-R diagrams for databases. We are striving for a structure with which to divide the knowledge base into smaller partitions that have a similar structure. This is a requirement for any form of useful knowledge analysis, validation, and maintenance [51].

The knowledge-level model itself is a tool that helps us clarify the structure of a knowledge-intensive information processing task. The knowledge-level model of an application provides a specification of the data and knowledge structures required for the application. The model is developed as part of the analysis process, but it does not contain any implementation-specific considerations.

In this thesis, we have proposed knowledge-level models which include two components: the Strategic Model (SM) and the Concerns Model (CM). The Strategic Model will provide a good understanding of the patient-education environment. The Concerns Model will provide a way to simulate how to address the concerns of different agents.

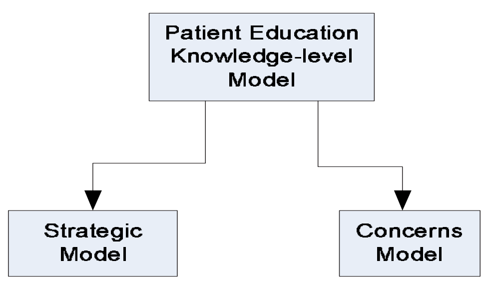

Figure 4.1: Knowledge-level Model Structure for Patient Education

4.2.2 Strategic Model

The success of patient education relies on a good understanding of the application environment. We need to identify who is involved in patient education (the stakeholders) and what are their objectives. We also need to find out why the objectives exist.

Strategic planning is a way to identify future states and develop plans to reach goals and objectives in an organization or an enterprise. We will use the concept of strategic planning to design a Strategic Model and express our objectives for patient education.

The Strategic Model will provide us with the basis for focusing on the reasons behind the activities of patient education and allow us to take actions directed towards the achievement of objectives. Our Strategic Model is based on two components: agents and objectives. We will discuss them individually.

Agents

An agent is an entity, such as a person, who can carry out certain tasks. Defining agents clarifies their roles in the patient-education process. An agent may interact with its environment and with other agents. It makes decisions, such as whether it should cooperate with other agents.

Our agents include the stakeholders in the education process. A stakeholder is an agent who has interests and a role in some process. The original meaning of 'stakeholder' is that a person who holds money or other property while its owner is being determined. Now the concept has been broadened to include everyone with an interest (or 'stake') in what an entity does. In patient education, stakeholders are individuals or organizations that are actively involved in, or whose interests may be affected as a result of, patient education. Stakeholders may also exert influence over the patient-education process and its results. An educator must identify the stakeholders, determine their requirements, and then manage and influence those requirements to ensure a successful learning experience. Therefore, the patient-education process must consider all stakeholders.

In the patient-education process, we identify the following stakeholders. Each of them can be regarded as an agent:

- Health care professionals: Health care intervention is often complex. It involves multi-step procedures and multiple professionals, which include clinicians, such as doctors and nurses. From the patient's prospective, they are all health care professionals and any of them may provide information to have a stake in her care.

- Patients: The patient is the person experiencing illness and treatment. She is a participant in the treatment and the consumer of the information.

- Family members: During the intervention, family members sometimes act as caregivers, so they also have concerns related to health care interventions and problems that emerge. Family members may have an interest in obtaining information about the care of the patient.

- Administrative staff: Administrative staff usually do not participate in the intervention directly, but they may have interest in treatment-related issues. This includes managing the cost of care and assuring treatment quality. They are also stakeholders and agents in the patient-education process.

- Patient Educator: The patient educator is the person who creates materials and provides information to educate patients about their health conditions, proposed treatment plans, and/or other things related to their interventions.

Each stakeholder is an individual or group and each has a role in patient education. In this thesis, to simplify the model, we consider only the three key stakeholders: the patient, the clinician, and the educator.

As detailed in Chapters 2 and 3, constructivist theory is the foundation we use to guide patient education and knowledge-level modelling. In order to use Constructivism in this work, we will regard a constructivist educator as a 'virtual' agent who creates educational materials. We associate this agent with the clinician, meaning we assume that the clinician *is* the constructivist educator. This agent works as the link between patient and clinician. Using this agent, we are able to ensure that the concepts of Constructivism are applied to the education of the patient.

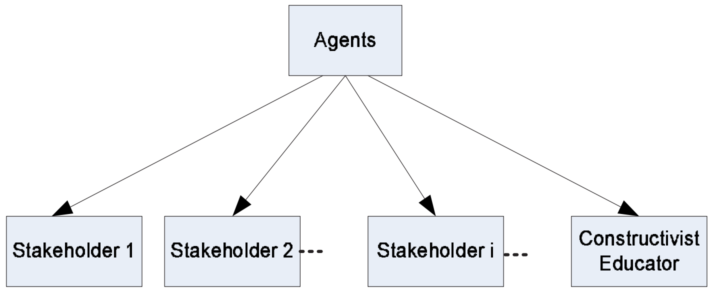

Figure 4.2: Agents Structure

Based on each agent's interests and roles in the process of patient education, he/she has objectives or goals to achieve.

Objectives

Objectives are states that agents want to achieve. The objective is specific in that it details exactly the what, where, and how of what is to be achieved. An objective is also action-oriented through 'activity indicators' which insure that the problem will be alleviated. As with objective-setting, we will use action-oriented verbs, such as *address, achieve, perform,* and *influence*. For example, one of the objectives of the health professionals is: "Comfort the patient".

Objectives are considered from each agent's point of view. For example, Table 4.3 lists the objectives, derived from each agent's point of view, in a surgical intervention.

Objectives need to be quantifiable so that we can determine if they have been achieved. In patient education, achievement of objectives is usually measured by the resulting change in behaviour.

Agents	**Objectives**
Patient	Become informed
	Be comfortable
	Get surgery done
Health professionals	Obtain informed consent
	Comfort the patient
	Perform surgery on patient
Constructivist educator	Address specific patient's information requirements
	Achieve behavioural outcome
	Influence patient's emotion

Figure 4.3: Objective Model

In our Strategic Model, one agent can have several objectives, and one objective may be associated with different agents. Figure 4.4 illustrates this.

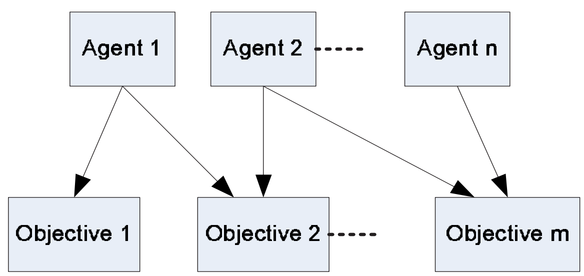

Figure 4.4: Strategic Model Relationship

4.2.3 Concerns Model

According to the WordNet Lexical database [62], a concern is "something that interests you because it is important to you or affects you"; it is also "something that causes anxiety". Each agent has concerns, and some agents also jointly hold concerns with others.

As discussed in Chapter 2, a patient selectively seeks help with problems that she is experiencing and looks for information about how to deal with them. The worry and concern associated with these problems often block a patient from actively participating in her intervention. The Patient-centric and Behaviour-modifying Educational Model illustrated in Chapter 2 supports the patient in applying learned knowledge and undertaking action for her own health. As the information provided to the patient must address the various concerns of different stakeholders, and different patients have different concerns and concern intensities, a Concerns Model is needed to guide the construction of concerns from different agents.

We recognize the importance of assessing individual situations in order to see the patient as she sees herself. Only then can we assist the patient in recognizing and overcoming obstacles that impair the achievement of desired behaviours.

Concern Topics

In patient education, each agent has a set of concerns. However, most concerns are generated by the patient and the primary health care professional. The health care professional's purpose is to obtain informed consent from the patient and get the patient engaged in the health care process. The patient wants to feel comfortable while participating in her treatment and wants to improve her own health using information obtained through the education process. In medical interventions, general concerns include pain, complications, disfigurement, risks, and benefits.

Concern Dimensions

In our Concerns Model, we regard concerns in at least two dimensions, which means there are at least two factors that affect concerns:

- The concern intensity, which is the motivational level perceived by the individual agent who has this concern.

- The factual level, which is the likelihood that the concern will actually affect the patient.

Before we define the concern intensity and factual level of each concern, we need to define an intensity or level scale. For example, we can define a three-level scale: *'low', 'moderate', 'high'*, for the concern intensity of a patient. *'Low'* means concern exists in the patient, but it is at a very low level. *'Moderate'* means that the patient has a certain degree of concern, but it is of medium level. *'High'* means that the patient's concern is critical.

The agent's concern intensity comes from her feeling and is determined by how much she worries about it or how important she considers it. For example, if a patient is fearful of pain, when she comes in for treatment she will have a *high* concern of pain.

The factual level is determined by treatment parameters and the patient's modifiers. The treatment parameters include treatment-related values, such as the treatment options and timing. The patient modifiers consist of the patient's characteristics or health status, such as obesity, diabetes, or smoking. Values of patient modifiers are either present (1) or non-present (0). A factual-level determination algorithm will be used to calculate the concern's factual level based on each parameter or modifier. Figure 4.5 explains the process described above.

Here is a simple determination algorithm:

Since not every parameter has the same effect on a concern's factual level, we define a weight for each parameter. For example, for *ith* parameter, suppose the weight is Wi, the likelihood that this parameter will effect the final factual level is Li, which is from 0 to 1. Then the actual effect of this parameter is $Pi{=}Li{*}Wi$. If there are totally n parameters, then the factual level for a concern subject Cj is: $Pji{=}\Sigma_{i=1}^{n} Lji{*}Wji$

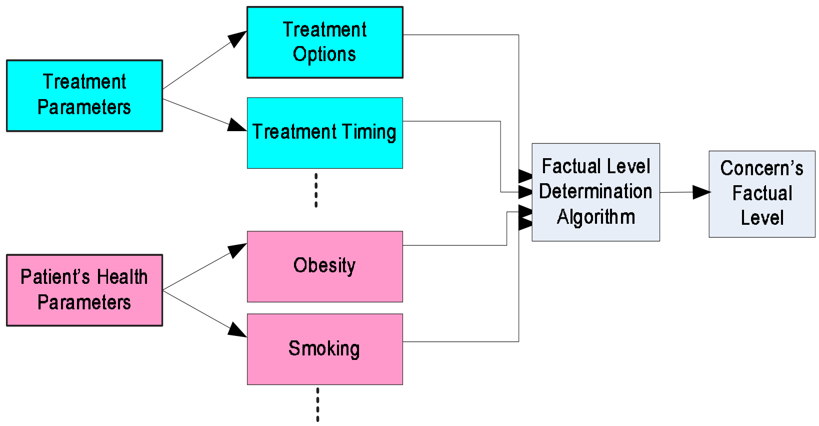

Figure 4.5: Concern Factual Level

The concern intensity and factual level together affect what kind of knowledge should be delivered to a particular patient.

Motivational and Informative Statement

We need to give a corresponding ordinary English statement for each level/intensity. The reason that we have the English statement is that it translates the abstract level or numeric intensity into a human-understandable description. Let us see how to construct a 'motivational statement' of the concern intensity and an 'informative statement' of the factual level .

For the 'motivational statement', it is easy to specify the concern intensity, but it is difficult to describe it in detail. Therefore, we simply translate the 'motivational statement' from the agent's concern intensity. For example, when a patient has a *'moderate'* fear of pain, the 'motivational statement' would be:

"You have moderate concern with pain."

As for the 'informative statement', the translation process is complicated. As mentioned above, the factual level is calculated by a determination algorithm according to the treatment parameters and patient's modifiers. Therefore, in order to address each concern topic clearly, we need to describe different aspects of the topic to reflect its various parameters and modifiers. For example, for a concern of pain, the aspects to be addressed in the 'informative statement' may include the following components:

- The degree of pain.
- How and when the pain starts.
- The location of the pain.
- The characteristics of the pain.
- How the pain is affected by activities.
- What improves or aggravates the pain.

These components will be organized in a specific discourse structure that the health care professional can follow in constructing his description. Still using the example of pain, the discourse structure might be:

Informative statement= *[The degree of pain.] [How and when the pain started.] [The location of the pain.] [The characteristics of the pain.] [How the pain is affected by activities.] [What improves or aggravates the pain.]*

Therefore, the informative statement has an internal discourse structure. For different concern topics, the discourse structures will be different. For example, for the concern of risk, the 'informative statement' will be considered from the aspects of 'what kinds of risk' and 'why it is a risk'. These components will make the internal discourse structure quite different from that of pain. For the same concern topic, each level of concern uses the same internal discourse structure, though the content is different.

Concerns Model Structure

Let us look at how the Concerns Model is constructed by combining the concern's two dimensions. First, an agent, which could be the patient, health care professional, or someone else, defines the 'motivational concern intensity'. Second, the 'factual concern level' is determined by the health care professional, according to the determination algorithm described above. Therefore, the 'motivational statement' is constructed according to the corresponding 'motivational concern intensity', and the 'informative statement' is constructed according to the corresponding 'factual concern level'. Afterwards the constructivist educator integrates these two statements and formulates the 'constructivist statement'. In the formulation process, knowledge elements from a medical knowledge base serves as the input to construct a 'constructivist statement'. Figure 4.6 shows the modelling process of the Concerns Model.

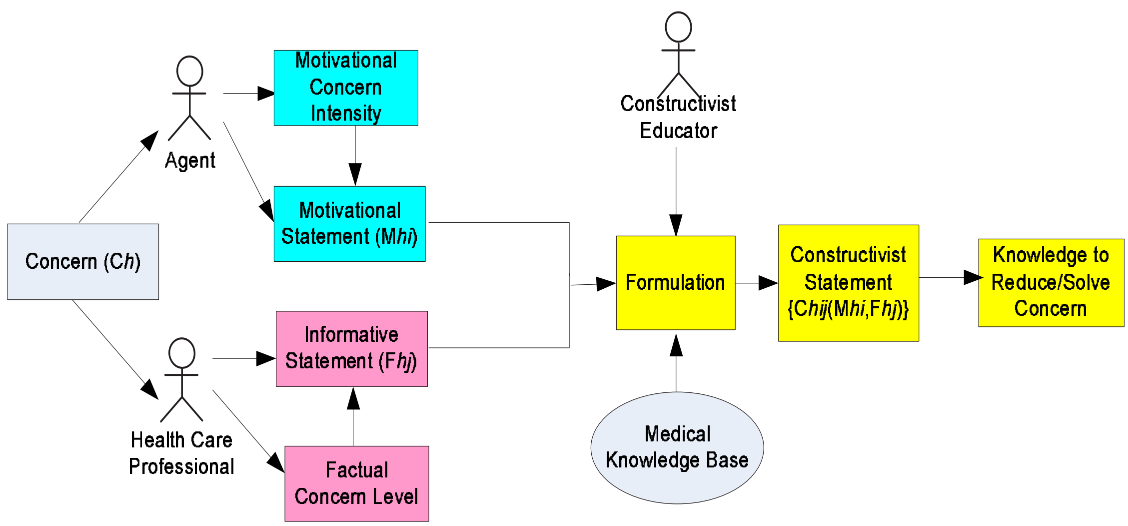

Figure 4.6: The Concerns Model

In our knowledge acquisition framework, the health care professional will be guided through this process. Also this process will allow him articulate and formulate his knowledge from different agents' point of view for each concern topic at various levels and intensities.

Let us symbolize the formulation process. Given *Ch*, where h corresponds to the *hth* concern. Let *Mhi* represent the 'motivational statement' (i corresponds to the *ith* level in the concern intensity scale), *Fhj* represent the 'informative statement' (j corresponds to the *jth* level in the factual scale), and *Chij* represent the 'constructivist statement'. We then use the following formulation to express their relationship:

Constructivist statement=*Chij(Mhi, Fhj)*

$1 \leq h \leq p$, if the total number of the concerns is p,

$1 \leq i \leq n$, if the motivational level scale is from 1 to n,

$1 \leq j \leq m$, if the factual level scale is from 1 to m.

Concern Matrix

By going through the above modelling process, each concern will be presented at various motivational intensities and factual levels. However, we need a data structure to assist in the Concerns Model's construction to accommodate the acquired knowledge. As each concern is considered from two aspects, a two-dimensional matrix is a good format for representing the related knowledge. Figure 4.7 shows our Concern Matrix.

We will need a Concern Matrix for each concern topic. Each matrix's structure may be slightly different. As Figure 4.7 shown, the motivational concern intensity and the factual concern level construct the two dimensions of the matrix, so the intensity scale or level scale determines the number of rows or columns of the matrix. With matrix's two dimensional structure, the motivational statement, informative statement, and constructivist statement could be easily filled in.

Constructivist Statement {C*hij*(M*hi*, F*hj*)}	**Factual Concern Level**	**Level 1**	**Level 2**	**…**	**Level *j***	**…**	**Level *m***
Motivational Concern Intensity	**Informative Statement (F*hj*)** / **Motivational Statement (M*hi*)**	**F***h1*	**F***h2*	**…**	**F***hj*	**…**	**F***hm*
Intensity 1	**M***h1*						
Intensity 2	**M***h2*						
…	**…**						
Intensity *i*	**M***hi*				**C***hij***(M***hi*, **F***hj***)**		
…	**…**						
Intensity *n*	**M***hn*						**C***hnm***(M***hn*, **F***hm***)**

Figure 4.7: The Concern Matrix

4.3 Interrogation-Based Knowledge Acquisition Tool

As described above, the Strategic Model and the Concerns Model together provide the knowledge structures for our knowledge acquisition framework. Now we need a knowledge acquisition tool to assist the health care professionals in articulating their knowledge.

Knowledge acquisition (KA) is the process of acquiring the knowledge needed for knowledge-modelling and problem-solving. The raw knowledge may be vague, incomplete, and incorrect in its initial form. However, through the process of elicitation, more complete knowledge may be constructed and made available for use.

Current KA techniques work well at procuring explicit knowledge from published sources but are ineffective for acquiring a domain expert's tacit knowledge. KA systems for creating customized patient-education material are quite different from other systems. Their focus is on acquiring knowledge for the Strategic Model and the Concerns Model to construct the discourse structure prior to actual-text-content authoring, both of which depend on domain expert's tacit knowledge. Therefore, we will use an alternative technique, Interrogation, for our knowledge acquisition framework. Interrogation is a technique that an investigator uses when questioning an arrested suspect intensively, guided by an internal logic structure. It is a technique that could capture formal knowledge and guide the constructing of the knowledge models. Interrogation is not a new concept, but this is the first time it has been applied to knowledge acquisition.

We begin by reviewing the nature and characteristics of different KA techniques, then introduce the Interrogation concept and describe how to use it in our knowledge acquisition process.

4.3.1 Review of Knowledge Acquisition Techniques

Knowledge acquisition, also called knowledge elicitation, attempts to obtain knowledge from a domain specialist, or from other information resources, through some form of interaction. Knowledge engineers may be able to gather information from a variety of nonhuman resources, such as textbooks, technical manuals, or case studies. However, as knowledge engineers usually do not have deep knowledge of the application domain, generally they still need to consult domain experts to gain knowledge beyond that in a non-human resource.

Our work is based on the idea that we would like to use techniques that minimize the effort spent gathering and analyzing an expert's knowledge and maximize the production of usable knowledge. Five types of techniques frequently used to articulate an expert's knowledge are: Interviewing, Protocol Analysis, Laddering, Concept Sorting, and Repertory Grids. Each of them has its own strengths and weaknesses. Our review materials are mostly from Schreiber and Akkermans [51].

Interviewing

Interviewing is the most commonly used knowledge acquisition technique. It takes many forms; examples include a completely Unstructured Interview and a formally planned Structured Interview.

For Unstructured Interviews, there are few constraints. They can be used whenever the expert and the knowledge engineer have a good relationship. There are no formal barriers to the discussion and the engineer can easily acquire a broad view of a topic. However, lack of constraints may lead to concentration on topics whose importance is thereby exaggerated.

The Structured Interview is planned and directed by a knowledge engineer. This type of interview is very straightforward. The interviewer has a standard set of questions that are asked of the domain expert. This makes it easier for the knowledge engineer to evaluate the interview result.

One problem with interviewing is that domain experts can only provide knowledge that they can articulate and there is still knowledge left in their minds which is hard to articulate. Because of this, Interviewing is usually supplemented by other methods.

Protocol Analysis

Protocol Analysis is a generic term for analyzing a process, performed by a domain expert, which allows him to solve problems in the domain. First, a record, such as a video, audiotape, or notes, is captured by the knowledge engineer. Secondly, protocols are then designed to represent what occurred in the record, and the knowledge engineer attempts to extract meaningful structure and rules from these protocols.

In Protocol Analysis, the knowledge engineer must be sufficiently acquainted with the domain to understand the expert's tasks. Scenarios in the video or other record should be very representative and are presented in a manner as close as possible to a real situation. Protocol Analysis is useful in analyzing dynamic reasoning behaviour, specifying tasks, and inferring knowledge. Like the Unstructured Interview, Protocol Analysis may deliver unstructured transcripts which are difficult to analyze. Protocol Analysis typically focuses on problem cases, it is difficult to derive general domain principles from a limited number of protocols.

Laddering

Laddering is a technique where the expert and the knowledge engineer construct a graphical representation of the domain in terms of the relationship between that domain and its problem-solving elements. The graph takes the form of a tree. The ladder tool enables the user to build various hierarchies of knowledge. These hierarchical diagrams are referred to as ladders. An example of part of a ladder created using the ladder tool is shown in Figure 4.8. Colours have been used to distinguish between types of objects and types of relations.

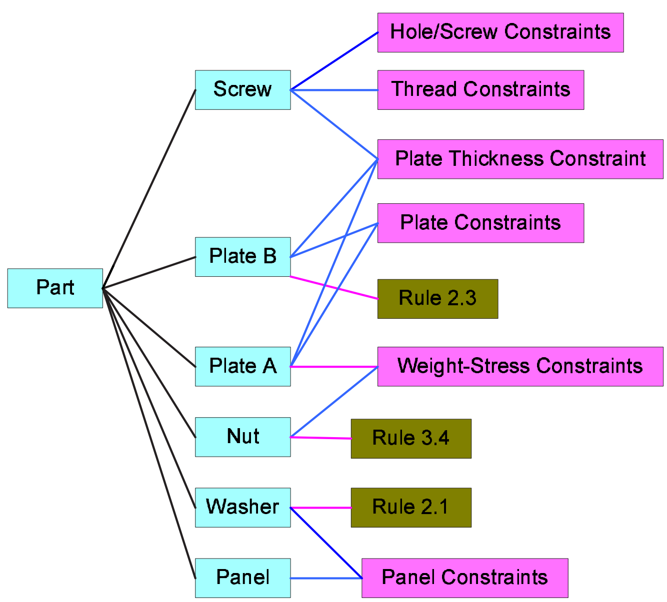

Figure 4.8: A Ladder Example

Laddering is typically used in the early phase of domain exploration.

Concept Sorting

Concept Sorting is useful when we wish to uncover the different ways that an expert sees relationships between a fixed set of concepts. It is quick to apply and easy to analyze. It helps the expert see structures in the domain which he himself has not consciously articulated previously.

With Concept Sorting, an expert is presented with a number of cards each displaying the name of a concept. The cards are shuffled and the domain expert applies some criteria to sort the cards into a number of piles such that the cards in each pile have something in common. This process is repeated. Each time the expert sorts the cards, he should create at least one pile that differs in some way from previous sorts. For example, a domain expert in astronomy might sort cards, showing the names of planets, into those that are very large, those that are medium size, and those that are relatively small. This technique provides multiple views of the structural organization of knowledge by asking the expert to do the same task over and over again.

Concept Sorting can discover new concepts and attributes, and is helpful in constructing a domain schema for unfamiliar domains. It requires some pre-structuring of the data through markups of interview transcripts.

Repertory Grids

This technique is designed to reveal a conceptual map of a domain in a manner similar to the card sort. For Repertory Grids, subjects are presented with a range of domain elements and asked to choose which are similar and which are different. The reason for differentiating is then asked. This process continues until the expert thinks there are no further discriminating constructs. The result, which will be in the form of a matrix of similarity ratings, relating elements, and constructs, will then be analyzed by using a cluster analysis method. An example of such a matrix is shown in Figure 4.9. The

Repertory Grid should be built interactively and at the conclusion of the process the expert is shown the resultant knowledge. Similar to Concept Sorting, this technique is useful when trying to uncover the structure of an unfamiliar domain. It is used mainly to support the specification of the domain schema.

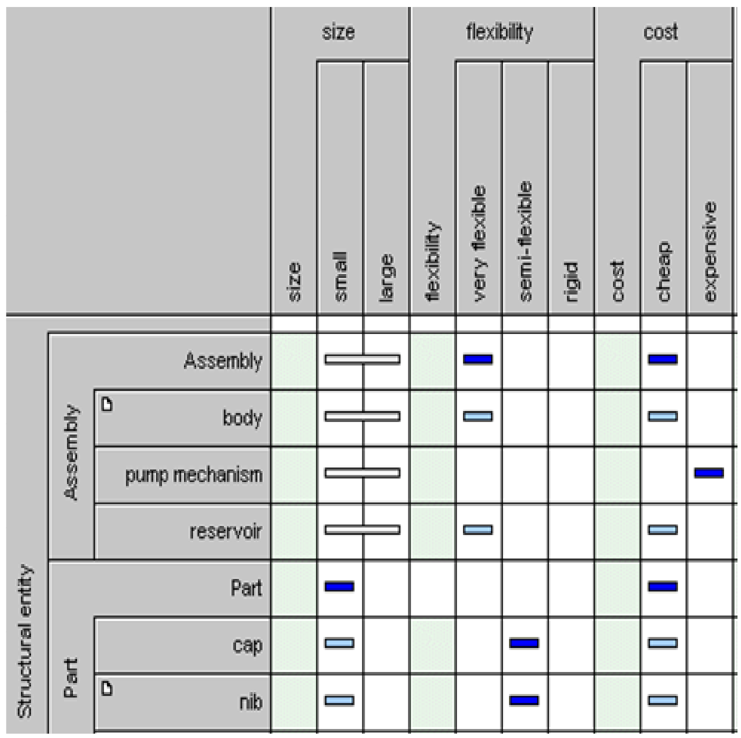

Figure 4.9: A Matrix Example

4.3.2 Why We Need a New Knowledge Elicitation Technique

As described above, each acquisition technique has strengths and weaknesses and is used in a different phase of knowledge acquisition. However, it is difficult to obtain formal descriptions from any elicitation technique. This difficulty is explained by evidence that imposing a formal structure on elicitation typically causes strong biases in the process, which then leads to acquisition of incomplete or bad data. Therefore, converting the elicited knowledge into a more formal description of the problem-solving process has been left to knowledge modelling. [51]

Knowledge modelling only provides a partial representation of the reality that needs to be constructed by the domain expert. If we do not get complete and formal knowledge through knowledge elicitation, we will have to develop a middle-ware representation[21] to translate human-understandable informal knowledge into a formal representation that could fit in the knowledge model. One approach to avoiding this middle-ware is to develop a technique that could capture formal knowledge and use it directly to construct the knowledge model. A more logically organized structure for the capture of the knowledge is needed. We have developed such a technique based on the Interrogation concept.

Interrogation and Knowledge Elicitation

Interrogation is not a new concept—it is a technique for intensively questioning a suspect in order to obtain information regarding crimes. It is also used by the military to extract information from captives about enemy operations. A well-conducted Interrogation uses a systematic interview process. A typical Interrogation involves three people: interviewer, interviewee, and note-taker. The interviewer usually asks short open-ended questions and attempts to establish a friendly rapport with the interviewee, speaking in a neutral or sympathetic voice. The note-taker watches the interaction between the interviewer and the interviewee, paying particular attention to behaviour and body language. Figure 4.10 shows the triangular relationship between them.

As Interrogation is a formal, systematic questioning process, the interviewer has theoretical knowledge or evidence and his own internal logic structure. The interviewer also has clear goals. These objectives will guide the interviewing process so that Interrogation becomes a goal-oriented process. On basis of the above analysis, we can see that Interrogation is similar to the Structured Interview method described in Section 4.3.1. However, in a Structured Interview, the interviewee has more freedom to express his own ideas. In an Interrogation process, the interviewee may be unable or reluctant to articulate his knowledge. But with internal logic structure, the interviewer completely guides the Interrogation process by forcing the interviewee to articulate his knowledge and capturing it.

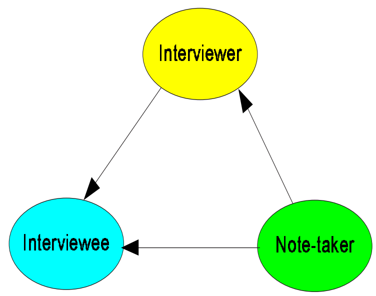

Figure 4.10: Interrogation Triangle

4.3.3 Applying the Interrogation Technique to Knowledge Acquisition

According to the description above, Interrogation is a formal, systematic questioning process and the interviewer has his own internal logic structure. Therefore, Interrogation is a technique that could capture formal knowledge and construct the knowledge models.

In previous section, a Strategic Model and a Concerns Model are defined. The Concern Matrix described is an appropriate complex knowledge structure to represent our Concerns Model and its knowledge: the two dimensions of the matrix could easily represent the concern according to the factual level and motivational intensity, and the cells will hold the formulated constructivist statements. However, it may be difficult for the health care professional, who is not a knowledge engineer, to do the motivational or informative statement translation and perform the role of constructivist educator for the formulation. Therefore, our knowledge acquisition tool needs to apply the concept of Interrogation and generate guidelines for the health care professional to follow. By providing guidelines, it will direct the health care professional in the formulation of the constructivist statement step by step for each cell of the matrix.

By applying the Interrogation technique, the acquisition tool will perform the role of interviewer, the health care professional will be the interviewee, the matrix will be the note-taker, and the guidelines will influence the way the health care professional articulating his knowledge.

Figure 4.11 shows the work flow of our knowledge-acquisition tool. In this tool, the interrogation process has two parts: the first part guides the health care professional to specify the Strategic Model and the Concerns Model by using the basic structures of these two models; the second part questions the health care professional to formulate the statements and fill in the Concern Matrix. As we can see, actually, our interrogation process starts from the beginning of the knowledge models' construction.

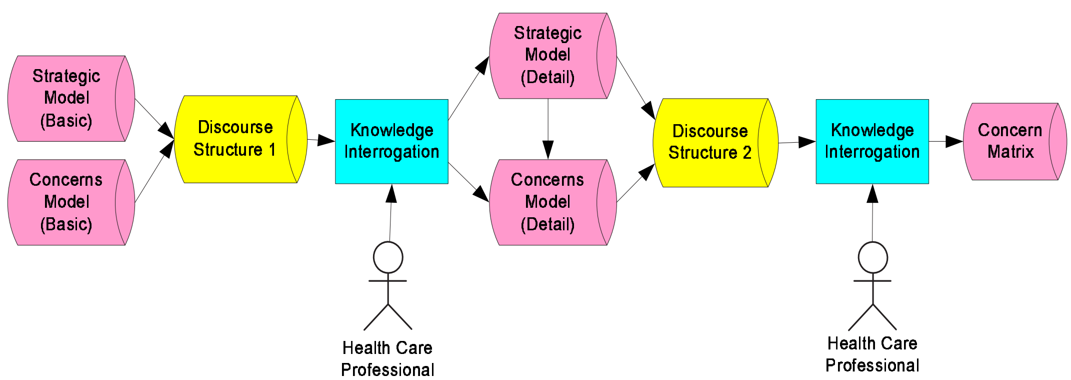

Figure 4.11: Work Flow of the Knowledge-acquisition Tool

Corresponding to above process, the guidelines have at least two internal discourse structures.

The first discourse structure is used in the initialization phase of the knowledge acquisition and may include the following components:

- Define the stakeholders of this medical intervention.
- Define the objectives of each stakeholder.
- Define the concern topics of each stakeholder.
- Define the factual level scale for each concern.
- Define the motivational intensity scale for each concern.
- Define the discourse structure of the informative statement for each concern.
- Define the informative statement for each factual concern level.
- Define the motivational statement for each concern intensity.

Interrogated by above questions, the health care professional can easily define the concern topics, the motivational concern intensity scale and the factual concern level scale for each topic, and the discourse structure for the informative statement for each topic. Knowledge acquired in this process will provide a baseline for the constructivist statement's formulation process.

After we acquire the basic knowledge, the second discourse structure is generated by combining it with the Concern Matrix. It also applies the discourse structure of informative statement we discussed above. The discourse structure may include following components:

- What is the motivational concern level?
- What is the motivational statement?
- What is the factual concern level?
- What is the informative statement?
- What are the tools, drug, or method to solve the concern?

- How the tools, drug, or method will be used?
- What is the constructivist statement generated from all of above elements?

There are different ways to structure these components, but the first part always translates the level or intensity to a corresponding statement, and the next part is always about the solution to the concern. The last part puts together the elements addressed above and generates constructivist statement.

These guidelines will be applied to each cell in each Concern Matrix, finally we will get a full knowledge matrix for each concern.

4.4 Design of a Knowledge Acquisition Tool

As described in Chapter 3, the knowledge acquisition process is one of the modelling activities. Knowledge modelling builds a generic problem-solving model first and then acquires the domain knowledge required to configure the problem-solving model. So a knowledge acquisition system provides a tool to support interactions with domain experts in order to construct the knowledge-level models and assist them in articulating their knowledge. In the case of patient education, the health care professional is the domain expert who possesses the knowledge with which the patient is to be educated. This tool will implement our knowledge modelling process and apply the Interrogation technique to elicit health care professionals' knowledge, which will be used by patient to construct her own knowledge and apply it to her medical intervention.

However, in this thesis we only briefly describe the system specification for a knowledge-acquisition tool, such that it can be used as a reference for detailed design and implementation of the tool in the future. It is because the focus of this thesis is to construct the discourse structure at the knowledge level for patient education materials prior to actual-text-context authoring, we developed a Patient-centric and Behaviour-modifying

Educational Model and a knowledge-acquisition framework to accommodate that. Also the knowledge-level modelling approach leaves the implementation related issues behind. Therefore,

The knowledge-level models and their knowledge contents, as discussed in the previous section, can be viewed as a specification of the problem-solving requirements. The knowledge-level model itself is a tool that helps clarify the structure of a knowledge-intensive information-processing task. As for our own knowledge-level models, the Strategic Model will provide a good understanding of the patient-education environment and serve as the basis for focusing on the reasons behind activities in a patient education; the Concerns Model will provide an approach for handling concerns from different agents. However, the models are developed as part of the analysis process, and therefore do not contain any implementation-specific considerations. In this section, we will define the functional requirements for a knowledge-acquisition tool. As a knowledge-acquisition tool, it needs to meet all the basic requirements of this kind of tool, such as knowledge elicitation and knowledge editing. However, because we are applying the Interrogation concept to knowledge acquisition for patient education, we also need to consider domain-specific requirements.

Functional Requirements

Functional requirements capture the intended behaviour of a knowledge-acquisition tool. This behaviour may be expressed as services, tasks, or functions that the system is required to perform.

A use case is the most common approach to identifying a software tool's required functions [7]. It is a means of obtaining system requirements from the user's perspective. It defines a goal-oriented set of interactions between external actors and the system under consideration. It bridges the gap between user-needs and system-functionality by directly stating the user's intention and the system's response at each step in a particular interaction. Thus, the use case captures which actor does what during which interaction with the system, and for what purpose, without dealing with system internals. A complete set of use cases specifies all the different ways to interact with the system, and therefore defines all behaviours required of the system, bounding the scope of the system.

In a use case, actors are parties outside the system that interact with it. In patient education, there are two actors: the health care professionals and the knowledge engineers. Because our purpose is to design a tool to be used by the health care professionals directly, to articulate their knowledge and reduce the work of the knowledge engineer, the health care professionals are the main actors and are involved in all activities. The knowledge engineer's only possible participation is in knowledge editing; his role is very limited.

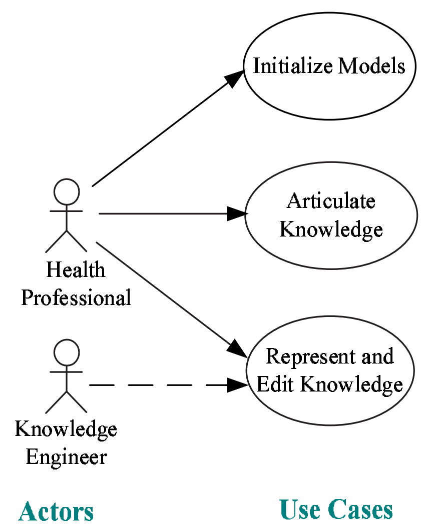

Figure 4.12: Interrogation-based Knowledge Acquisition Use Case Diagram

A use case is initiated by a user with a particular goal in mind, and is completed successfully when that goal is satisfied. It describes the sequence of interactions between actors and the system necessary to deliver the service that satisfies that goal. The system is treated as a 'black box', and interactions with the system, including system responses, are presented as perceived from outside the system. [7] Our knowledge-acquisition tool has three associated use cases: initializing models, articulating knowledge, and representing and editing knowledge. (See Figure 4.12).

Use Case 1: Initialize Models

Our system has the basic structures for knowledge-level models which are common to several domains and can be shared by these domains. However, if this system is used to acquire knowledge for a specific domain, such as a breast reconstructive surgical intervention, the health care professionals need to initialize the models according to the features of this domain. Thus we can get the complete structures to accommodate the knowledge of this domain.

As described in the previous section, we have two knowledge-level models: the Strategic Model and the Concerns Model. These two models will be initialized during this process.

Use Case 2: Articulate Knowledge

After the knowledge-level models are set up, the next step is to interrogate the health care professional. As discussed in the previous section, we apply the Interrogation concept to the knowledge-acquisition process. So, in this use case, knowledge-level models initialized in the first use case will be the basic structures that assist the health care professionals in articulating their knowledge. However, since the model structures are quite abstract, they are difficult for the health care professionals to follow. Therefore, guidelines will be given so that health care professionals can easily follow and articulate their knowledge step by step.

In this process, the health care professionals are the actors and continuously interact with the system.

Use Case 3: Represent and Edit Knowledge

The knowledge acquired in the 'Articulate Knowledge' use case is placed into the knowledge model structures, but is then organized for convenience of representation and reasoning mechanisms of the computer system, rather than for human beings. Therefore, in addition to knowledge Interrogation, we need to describe the representation and editing of the captured knowledge. The pieces of knowledge should be easily edited by the health care professionals and become readable by those who were not involved in the original knowledge authoring, such as the health-education writer.

Visual representation of the knowledge structures with the potential for editing and enhancement is an attractive way of dealing with the results of elicitation. Many other knowledge-acquisition tools leave knowledge presentation and editing to application tools which are separated from the acquisition tools [21]. If we could incorporate an editor into the knowledge-acquisition tool that interacted effectively with all the different forms of knowledge captured, the knowledge-acquisition tool would be more useful.

A knowledge-acquisition tool should be implemented applying the above use cases. This tool should be designed to provide an efficient and effective means of knowledge capture, and present captured knowledge and its structures for easy editing and reviewing. Integrating the knowledge representation and editing function into the system allows health care professionals or those who are interested to play with the knowledge: changing or editing it.

4.5 Summary

In this chapter, we described a new Constructivism-based knowledge-acquisition framework for patient education. This framework provides a basic structure for understanding knowledge-level models and creates a Interrogation-based knowledge-acquisition tool to supplement the HealthDoc Project's authoring tools from another level: the knowledge level. We also defined use cases as the functional requirements specification for such a knowledge-acquisition tool.

Chapter 5

Case Study—Breast Reconstructive Surgery

In the previous chapter, we described a Constructivism-based knowledge-acquisition framework for patient education. The Strategic Model and the Concerns Model provide internal structures for the knowledge-level modelling. The knowledge-acquisition tool implements the modeling process and applies the Interrogation concept to assist the health care professional in articulating his domain knowledge. To provide evidence for the viability and usefulness of the framework, we will walk through a case study to demonstrate how to use the tool for interrogating the health care professionals. We use the education of a patient prior to breast reconstructive surgery as our case study. The reason that we selected breast reconstructive surgery is because it is one of the most complex interventions in modern surgical oncology and involves multi-step procedures and multiple options. In addition, this type of surgery raises serious concerns in many patients. This creates a need for a patient to have treatment options and information explained to her.

In this chapter, we first introduce background information regarding breast reconstructive surgery in section 5.1. Then in section 5.2, an example of the interrogation process is demonstrated.

5.1 Background on Breast Reconstructive Surgery

Women undergo reconstructive breast surgery for various reasons. Some of them wish to have their breasts reconstructed for cosmetic reasons, i.e., they perceive their breasts to be too small or too large. However, most patients seek surgery after a mastectomy performed for breast cancer. Breast cancer is the most frequently diagnosed cancer in Canadian women. According to the data of the Canadian Cancer Society [13], an estimated 21,200 Canadian women were diagnosed with breast cancer in 2004 and 5,200 died of it. On average, one in nine women is expected to develop breast cancer during her lifetime and one in twenty-seven women will die of it.

Due to new approaches in surgery, chemotherapy, hormonal therapy, immune therapy, and radiation therapy, breast cancer death rates have declined steadily since 1986. In fact, the most recent data reveal that the breast cancer death rate is at its lowest since 1950 [13]. Currently, most patients do not worry about dying from breast cancer, but an increasing number of women are concerned with the appearance and symmetry of their breasts following a mastectomy, and therefore undergo breast reconstructive surgery.

Breast reconstruction is a complex surgical intervention which includes multiple procedures to restore the appearance of the breast. The surgery rebuilds the breast contour and, if the patient wishes, the nipple and areola. The reconstruction is done by a plastic surgeon. There are many surgical options available to the patient [48]. To reconstruct the breast, the surgeon can use an artificial implant, a flap constructed of the patient's own tissue, or a combination of the two. The artificial implant could be filled with either saline or silicone gel. The tissue flap could be transplanted from the abdomen, back, or other area of the body. The flap could be pedicled or free. Pedicled flaps are those that have their original blood supply intact, whereas free flaps are lifted free and detached from their original locations. Figure 1.1 in Chapter 1 shows a partial informal decision tree for breast reconstructive surgery. By examining this tree, we can clearly get a sense of the complexity of the breast reconstruction decision process. What is more, each reconstructive option is associated with different advantages, disadvantages, and perioperative implications. These differences make it necessary to customize educational information provided to the patient. In Table 5.1 [48], the implant-related knowledge is divided into pieces according to the conditions, contradictions, advantages, and disadvantages of the implant option. As shown, the knowledge is very complex.

Implant option	**Knowledge**
Conditions	Breast needs to be smaller, minimally ptotic (droopy)
Contradictions	1. Has undergone extensive skin excisions with tight closures and thin flaps 2. Scheduled to have chest wall radiation
Advantages	1. Shorter operative procedure 2. Shorter hospital stay 3. Shorter recovery time 4. Produces relatively predictable breast shapes in most women 5. Leaves fewer scars (i.e., no new scars on other areas of the body)
Disadvantages	1. Difficult to make a large, slightly ptotic (droopy) breast 2. Produce less natural breast shape 3. The expansion process is time-consuming and may be inconvenient 4. Couldn't see the final breast shape immediately 5. An implant reconstruction may not respond well to subsequent radiation therapy 6. The expanders and implants may migrate and rupture 7. A capsular contracture (i.e., scarring and hardening of the breast) may occur which requires additional surgery to correct 8. 'Wrinkling' or 'rippling' of the implants may occur

Figure 5.1: Knowledge Related to the Implant Option

It is a challenge for both patients and surgeons to ensure that sufficient, understandable information has been communicated preoperatively regarding the surgery. Although preoperative information brochures provide useful information for patient education, a library of static documents would be difficult to establish if it were to encompass all reconstructive surgical alternatives. For a patient undergoing a multi-step procedure, a handful of brochures would be required. However, a collection of brochures might be confusing, especially given the likely lack of cohesiveness. Consequently, existing preoperative information brochures are only available for the most common surgical procedures and must, by necessity, remain generic in nature to ensure applicability to all patients. Customized patient education materials for breast reconstructive surgery would be valuable for both the surgeon and the patient.

In the next section, we will illustrate how to interrogate health care professionals to initialize the knowledge-level models and articulate their domain knowledge. As pain is the topic of greatest concern for most patients, we will use pain as our example to demonstrate the Concerns Model.

5.2 Interrogation-based Knowledge Acquisition

As discussed in Chapter 3, Constructivism-based knowledge-level modelling is the knowledge-acquisition paradigm that simulates human problem-solving processes, and constructs the knowledge base of the domain. In Chapter 4, we described a Strategic Model and a Concerns Model as the structures of our knowledge-level modelling. Here, we will detail the process for guiding health care professionals in the construction of these two models and the articulation of their knowledge by using our knowledge-acquisition tool.

5.2.1 Initialize the Models

First, our knowledge acquisition tool will guide the health care professional in initializing two models: the Strategic Model and the Concerns Model. Each of them will be specified according to the information about breast reconstructive surgery. Health care professionals will follow the first discourse structure described in Chapter 4 to do the initialization, which is as follows:

- Define the stakeholders of the breast reconstructive surgery.
- Define the objectives of each stakeholder.
- Define the concern topics of each stakeholder.
- Define the factual level scale for each concern.
- Define the motivational intensity scale for each concern.
- Define the discourse structure of informative statement for each concern.
- Define the informative statement for each factual concern level.
- Define the motivational statement for each concern intensity.

The Strategic Model

In the Strategic Model, we need to identify the agents that will be involved in patient education for breast reconstructive surgery, together with their objectives. In particular, the Strategic Model will provide help to understand the educational environment for the patient.

Define the Stakeholders

As detailed in Chapter 4, agents include stakeholders who have an interest in or are actively involved in patient education. As mentioned in Chapter 3, the health professional and the patient are the most important stakeholders in patient education. Let us look at these two types of stakeholders in breast reconstructive surgery:

- Breast cancer patient: As most patients considering breast reconstructive surgery are survivors of breast cancer, the breast cancer patient is a stakeholder and agent.

- Plastic surgeon: The plastic surgeon is the person who will perform the surgery on the patient. This surgeon will be the domain expert for our knowledge Interrogation tool and one of the agents.

We need to remember that the 'virtual' constructivist educator is an indispensable agent who applies constructivist theory to our modelling process. However, we do not need a separate person to perform the role of constructivist educator; in this situation the plastic surgeon will serve in a dual role.

Define the Objectives

Objectives are the outcomes that agents want to achieve through the education process. Let us look at the objectives of the patient and the plastic surgeon.

- Breast Cancer Patient's Objectives: For the patient, one objective might be becoming informed about the surgery. As mentioned in the previous section, a patient can elect the use of an implant, her own tissue flap, or a combination of the two for breast reconstruction . For example, as Table 5.1 shows, patients with smaller breasts who have undergone a total mastectomy are the best candidates for implant reconstruction. However, any patient who has undergone extensive skin excisions with tight closures and thin flaps might be better treated with a flap reconstruction instead of an implant reconstruction. Other objectives of the patient include feeling comfortable about the upcoming surgery and having the surgery performed successfully.

- Plastic Surgeon's Objectives: As for the plastic surgeon, his objectives could include achieving informed consent from the patient, comforting the patient, and successfully performing the breast reconstructive surgery on the patient. As the plastic surgeon performs the role of 'virtual' constructivist educator, his objectives also include providing information to address the patient's concerns, and helping the patient achieve desired behavioural outcomes and gain confidence.

We will present a concern matrix for each concern topic and provide guidelines so that the ‘virtual’ constructivist educator’s role can be easily performed by the domain expert, the plastic surgeon, who formulates the appropriate concern-resolving knowledge. See the next section for more information regarding the Concerns matrix.

The Concerns Model

The Concerns Model provides a structure to accommodate the domain knowledge. In this model, we first need to define all the concern topics, followed by a two-dimensional matrix serving as the data structure corresponding to each of the topics.

Define the Concern Topics

Concerns that must be addressed in patient education for breast reconstructive surgery include:

- Pain: There may be a degree of pain during the intervention or after it. Some patients express great concern regarding pain. Health care professionals have means at their disposal to control the discomfort.

- Complications: Complications may be associated with any intervention. Possible complications include: wound bleeding, draining, or infection. Smoking and other factors may increase the likelihood and severity of complications.

- Morbidities: In addition to associated with complications, morbidities may accompany any intervention. Possibilities include: nausea, fat necrosis, or seroma. Also, smoking and other factors may increase the likelihood and severity of morbidities.

- Disfigurement: Surgery usually leaves a scar on the patient’s body and may cause asymmetry of the body. The potential for disfigurement may reduce a patient’s engagement related to the treatment.

- Risk: Any interventions, especially surgical interventions, may be associated with possible negative outcomes, such as loss of function and disfigurement, and sometimes even loss of life. Health care professionals need to inform the patient about possible risks and help the patient understand them.

- Benefits: The reason that a patient agrees to an intervention is that it may benefit her. By understanding these benefits and balancing them against the risks, a patient can more easily decide for or against the intervention.

- Cost: The treatment may either be covered by government or a private health insurance plans, or paid by the patient herself. This information needs to be clearly addressed before the intervention.

- Preparation for the intervention: Instructions on how to prepare for the intervention should be provided to the patient. These include guidelines on eating and drinking, smoking, and taking or avoiding specific vitamins and medications for a period of time before intervention.

- Wound care: A wound is associated with most surgical interventions. There may be bleeding, draining, or scarring associated with the wound. Wounds may require special care.

- Activity: After the intervention, the patient may feel tired or sore, so the patient should follow the health care professionals' advice on when to begin, for example, stretching exercises, and resume normal activities. The right exercise generally will help a patient's recovery.

- Recurrence: Patients worry about recurrence. Patients need to realize the possibility that a disease will reoccur even after an intervention.

- Return to work: Some interventions may delay or prevent the patient's return to work.

Among these concerns, pain is the most common concern that most patients worry about. However, pain is also the most difficult topic for patients to describe, and each patient reacts very differently to it. Therefore, we use pain as a good example of a complex concern to illustrate how to use the Concerns Model.

The Concern Matrix

As discussed in Chapter 4, a two-dimensional matrix is a good format for the plastic surgeon to formulate the 'constructivist statement' and to represent the related knowledge. Figure 5.2 shows the matrix for the concern of pain.

Constructivist Statement {C*hij*(M*hi*, F*hj*)}	**The Level of Pain Likely to Actually be Experienced**	Nil	Mild	Moderate	High
The Level of Patient's perception of Pain	**Informative Statement (F*hj*)** / **Motivational Statement (M*hi*)**	**F***h1*	**F***h2*	**F***h3*	**F***h4*
Nil	**M***h1*				
Mild	**M***h2*				
Moderate	**M***h3*				**C***h34***(M***h3***, F***h4***)**
High	**M***h4*				

Figure 5.2: The Concern Matrix for Pain

In order to complete the Concern Matrix, the following steps need to be performed.

Define the Factual Level Scale

Pain will be considered from two aspects, the patient's perception of pain and the likelihood that the pain will actually be experienced. Here, we define same four-level scale: *'nil', 'mild', 'moderate', and 'high'*, for both the level of the patient's perception of pain and the factual level of pain likely to be experienced.

Define the Motivational Intensity Scale

As mentioned above, we define the same scale for both the factual level scale and the motivational intensity scale, which is *'nil', 'mild', 'moderate', and 'high'*.

For each level or intensity, we give a corresponding ordinary English statement describing the nature of the pain that is likely to be experienced or the patient's perception of pain.

Define the Discourse Structure of Informative Statement

For the 'informative statement', according to Chapter 4, the factual level is calculated by a determination algorithm according to the treatment parameters and patient's modifiers. Therefore, in order to address each concern topic clearly, we need to describe different aspects of the topic to reflect its various parameters and modifiers. For pain, the aspects to address in the 'informative statement' may include the following components [44]:

- The degree of pain. This is the intensity or severity of the pain likely to actually be experienced.
- How and when the pain starts. We will introduce what causes the pain and how it starts, i.e., gradually or suddenly. We should also explain how long the pain will persist.
- The location of the pain. We should indicate the area or point where it hurts or related to which the pain travels.

- The characteristics of the pain. This is how the patient might feel about and describe pain.
- How the pain is affected by activities. We should describe activities that increase the pain and also those that relieve it.
- What improves or aggravates the pain. We will illustrate situations that make pain better or worse. These might include changes in weather conditions, living or working environment.

These components will be organized in a specific discourse structure that the plastic surgeon can follow in constructing his description. For pain, the discourse structure might be:

Informative statement= *[The degree of pain.] [How and when the pain started.] [The location of the pain.] [The characteristics of the pain.] [How the pain is affected by activities.] [What improves or aggravates the pain.]*

Define the Informative Statement

This discourse structure applies to each cell of the pain matrix, though the content is different. For example, when the level of pain likely to be experienced is *'high'*, the 'informative statement' might be similar to this:

Fh4=(The degree of pain) "You may feel severe pain."

(How and when the pain starts) "You will feel pain after you wake up from anesthesia. Your pain may last a few days, but its intensity usually decreases."

(The location of the pain) "The pain or discomfort will be felt in the breast area or abdominal site."

(The characteristics of the pain) "Soreness and swelling are often part of your body's reaction to the trauma of surgery. There might be pain and tenderness under the surface."

(How the pain is affected by activities) "You should not perform lifting activities or anything that involves the muscles in the breast area or abdominal site. This would cause additional pain and prevent the healing of your wound."

(What improves or aggravates the pain) "Bad weather, such as rain or snow, might worsen your pain."

Define the Motivational Statement

As it is easy to specify the concern intensity of the pain, but difficult to describe it in detail, we just simply translate the 'motivational statement' from the patient's perception of pain. For example, when a patient has a moderate fear of pain, the 'motivational statement' would be:

Mh3="You have moderate concern with pain."

5.2.2 Articulate Knowledge

In previous subsection, we have gone through the process of specifying the Strategic Model by defining the agents and their objectives. We also initialized the Concerns Model by defining the concern topics and their discourse structures of informative statement. Now let us look at how the plastic surgeon uses guidelines to formulate constructivist statements by combining the knowledge acquired in initialization process.

We will use the guidelines described in Chapter 4:

- What is the motivational concern level?
- What is the motivational statement?
- What is the factual concern level?
- What is the informative statement?

- What are the tools, drug, or method to solve the concern?
- How the tools, drug, or method will be used?
- What is the constructivist statement generated from all of above elements?

Let us still use the example of pain. The discourse structure of informative statement described in previous subsection will be applied here. Suppose the level of the patient's perception of pain is *'moderate'* and the level of pain likely to be experienced is *'high'*. Here is the interrogation process that will help the plastic surgeon formulate his knowledge about pain:

What is the motivational concern level? Moderate.

What is the motivational statement? Patient has moderate concern with pain.

What is the factual concern level? High.

What is the informative statement?

(The degree of pain) "You may feel severe pain."

(How and when the pain starts) "You will feel pain after you wake up from anesthesia. Your pain may last a few days, but its intensity usually decreases."

(The location of the pain) "The pain or discomfort will be felt in the breast area or abdominal site."

(The characteristics of the pain) "Soreness and swelling are often part of your body's reaction to the trauma of surgery. There might be pain and tenderness under the surface."

(How the pain is affected by activities) "You should not perform lifting activities or anything that involves the muscles in the breast area or abdominal site. This would cause additional pain and prevent the healing of your wound."

(What improves or aggravates the pain) “Bad weather, such as rain or snow, might worsen your pain.”

What are the tools, drug, or method to solve the concern? Anesthesia, Acetaminophen, such as Tylenol, Panadol.

How the tools, drug, or method will be used? Anesthesia will be given before the surgery; and analgetics, such as Tylenol, Panadol, will be given every four hours around the clock.

What is the constructivist statement generated from all of above elements?

Ch34 = “ You may feel severe pain after you wake up from anesthesia. Your pain may last few days, but its intensity usually decreases. The pain or discomfort will be felt in the breast area or abdominal site. Soreness and swelling are often part of your body’s reaction to the trauma of surgery. There might be pain and tenderness under the surface. You should not perform lifting activities or anything that involves the muscles in the breast area or abdominal site. This would cause additional pain and prevent the healing of your wound. Bad weather, such as rain or snow, might worsen your pain. However, don’t worry, nearly all pain is treatable and we will help you control the pain. Anesthesia will be used, so you will not feel pain during the surgery. You may feel pain after the surgery, but we will give you analgetics, such as Tylenol or Panadol, to reduce or eliminate the pain. The medication will be given every four hours around the clock. If you take your medication as directed, your pain can be controlled without any significant risk of addiction or intolerance.”

After interrogating the plastic surgeon and acquiring his knowledge, the knowledge acquisition tool will place the motivational statements, informative statements, and the constructivist statements in our concern matrix. For each cell in the matrix the same procedures will be repeated. The result eventually is a full matrix with all the cells filled.

5.2.3 Represent and Edit Knowledge

From the above subsections, we can see that the knowledge-level authoring for pain is a very complex process: each piece of knowledge has to address various concerns from different stakeholders, i.e., the breast cancer patient and the plastic surgeon. However, our framework has a mechanism which makes it easier to represent and edit the knowledge:

- The Concerns matrix is a guiding structure for the creation of the knowledge.
- The two dimensions of the matrix provide the framework for the authoring tool to follow.
- The informative statement has its own internal structure for the plastic surgeon to follow.
- The guidelines generated by applying the Interrogation concept can assist the plastic surgeon in articulating his knowledge step-by-step.

Therefore, the representing and editing function of the acquisition tool can be implemented by taking advantage of the Concerns Model's internal structure.

Chapter 6

Conclusion and Future Work

This research was motivated by the HealthDoc Project, which developed a Natural Language Generation system for authoring and generating tailored patient-education materials. However, the work in the HealthDoc Project has focused on authoring at the level of actual-text-content. This thesis addresses the 'knowledge level' of authoring to propose a new patient-education model and a knowledge-acquisition framework, which are intended to create the underlying discourse structure for tailored patient education materials.

6.1 Research Contributions

Constructivist theory has been recognized as an epistemological approach that promotes learner-centric experiences and regards knowledge as constructed internally by individuals. In this thesis, constructivist theory is applied in the design of a new patient-education model and in the development of a knowledge-acquisition framework for patient education. Our Patient-centric and Behaviour-modifying Educational Model (PBEM) is a new patient-education model that attempts to simulate the knowledge transfer process in a constructivist approach to creating patient-education materials. The traditional patient-education approach views education as a simple knowledge transfer process: health care professionals provide factual information to the patient, and the patient is the passive recipient of the information. Unlike the traditional approach, which treats all patients similarly and simply informs them of the knowledge that health care professionals consider important, our approach considers the characteristics of each individual patient. This customized approach assists the patient in assimilating relevant knowledge and applying this knowledge to changing her behaviour and achieving her goals or objectives, such as feeling comfortable about the intervention. The new PBEM model guides us in the design and application of Constructivism-based educational materials.

By analyzing the different knowledge-acquisition paradigms, we concluded that Constructivism-based knowledge-level modelling is a better way to construct knowledge and solve knowledge-acquisition problems. Therefore, in Chapter 4, we proposed a Constructivism-based knowledge-acquisition framework for patient education. Our knowledge-acquisition framework consists of the following four components:

- The Strategic Model: The Strategic Model helps the user identify agents and their objectives so that they can understand the key elements of the patient-education environment. One main feature of the Strategic Model is that we engage the health care professional to serve as the constructivist educator agent. We guide the health care professional through the role of constructivist in the process of knowledge-level modelling.

- The Concerns Model: We consider that different patients have different concerns. The factual level and motivational intensity of these concerns vary from patient to patient. Also the factual level varies from surgery-type to surgery-type. The Concerns Model can assist us in recognizing obstacles that impair the patient from achieving desired behaviours.

- The Interrogation-based knowledge elicitation: We make a novel contribution to the knowledge acquisition field by introducing Interrogation as a knowledge elicitation technique, although it has been widely used by police and the military. Compared to other techniques, Interrogation is a formal, systematic questioning process which can be used to elicit knowledge from the interviewee. In our framework, this process is based on our initial structure of the Strategic and Concerns models.

- The knowledge-acquisition tool: We briefly specify three use cases which could be used for the functional design of a knowledge-acquisition tool. A knowledge-acquisition tool based on this work would have two parts: an elicitation tool and a representation and editing tool.

6.2 Future Work

In our case study, we have provided an example of breast reconstructive surgery and a concern topic of pain to demonstrate the viability of our knowledge-acquisition framework. However, there are still some issues that are beyond the scope of this research and have not been explored. Suggestions for future work include the following:

6.2.1 Implementation of an Acquisition Tool

In this thesis, we have concentrated on applying the constructivist approach to patient education to develop model of knowledge acquisition for authoring patient-education materials. We designed a knowledge-acquisition framework which provides a basic structure to help understand the knowledge-level models and the knowledge-acquisition tool, but we have left implementation as future work. However, we have defined the use cases for functional requirements. With Interrogation as our elicitation technique, what we need is not only an interactive Interrogation tool for acquiring knowledge, but also an editor to capture and edit the knowledge.

6.2.2 Specification of Discourse Structure For Each Concern Topic

We defined a internal discourse structure for the informative statement of the pain concern. However, a discourse structure for each concern topic would be required to complete the framework.

6.2.3 Completion of a Determination Algorithm

We gave a simple version of the determination algorithm for the factual level of concern topic and described it briefly in Chapter 4. A full algorithm is needed to precisely determine the factual level of the concern topic in all cases.

6.2.4 Integration with the HealthDoc System

The knowledge-acquisition tool we have outlined is intended to be part of HealthDoc's Natural Language Generation system. However, this tool, as well as the other system components, such as SPLAT [27], ESTUSS [3], and the authoring tool for surface text [45], have been developed separately. This has led to isolated 'islands' of disparate tools. In order to bring the HealthDoc Project to completion, we need a framework to integrate all these tools. With an integrated system, we would start from the knowledge acquisition phase and end with the output of the actual tailored patient-education materials.

Integration is very challenging however. The following list shows some possible reasons:

- There are many overlaps and interdependencies among these components;
- Each component tool contains information in a different format and structure, and uses different terminology to refer to the same concept.
- It is difficult to enable these components to communicate with each other because they have been developed in isolation.

Therefore, before integrating these tools, we need to understand each component's internal structure and data format and create a single solution for the integrated system. Also the relationship among these components should be clearly illustrated and communicated.

6.3 Conclusion

The patient-education model and knowledge-acquisition framework described in this thesis are the first step for knowledge-level modelling in the HealthDoc Project. The Patient-centric and Behaviour-enabling Education Model based on this constructivist approach provides further support and guidance for customizing educational materials to individual patients. Our knowledge-acquisition framework provides a detailed structure for the acquisition of knowledge needed for creation of patient-education materials.

This research has raised issues in the authoring of patient education that need to be addressed in the continuing development of HealthDoc and explores a new field, knowledge acquisition in patient education, that extends the overall scope of the project.

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