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**THE DEVELOPMENT AND TESTING OF A
KNOWLEDGE-BASED PATIENT SIMULATOR**

by Siobhan MacDonald, B. Comm.

**A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfillment of
the requirements for the degree of**

(Master of Management Studies)

**School of Business
Carleton University
Ottawa, Ontario.**

**Tuesday September 21, 1993
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**The Development and Testing of a
Knowledge-Based Patient Simulator**

submitted by Siobhan MacDonald, B.Comm.,
in partial fulfillment of the requirements for
the degree of Master of Management Studies.

Thesis Supervisor

Director, School of Business

Carleton University
September 21, 1993

Abstract

Recently, medical simulators have emerged as a viable instrument to use in assessing students' diagnostic and treatment skills. This study involved research on the development and the testing of a prototype of a knowledge-based patient simulator that was developed according to the KADS methodology. The KADS methodology is similar to conventional software development methodologies. The research opportunity consisted of two components. The first component involved determining if restructurable modelling was a suitable approach to simulate a patient's medical condition. The second component involved testing an application of restructurable modelling to determine if it is a suitable instrument with which to assess a student's diagnostic and treatment skills. The software package used in developing the patient simulator was Negoplan which is a shell based upon the principles of restructurable modelling. The simulator was tested by students, and the feedback provided was integrated into iterations of the prototype, resulting in a successful implementation of restructurable modelling. This prototype proved to be useful in assessing a student's diagnostic and treatment skills.

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Table of Contents

	Page
Acceptance Sheet	ii
Abstract.....	iii
Acknowledgments.....	iv
Table of Contents.....	v
List of Figures	vi
 Introduction	 1
Background	2
Clinical Decision-Making.....	3
Clinical Decision-Making Process.....	3
Clinical Decision-Making Approaches.....	4
Medical Education and Training	6
Classical Forms of Instruction	6
Classical Forms of Evaluation	7
Commentary on Medical School Curriculum	8
An Effective Medical Learning Process.....	9
Medical Education and Computers.....	11
Current Situation	11
Computer-Assisted Learning.....	12
Simulation.....	13
 Literature Review.....	 15
 Research Opportunity.....	 20
Prototype Development.....	20
Scope	20
Feasibility	21
Methodology.....	22
Analysis	24
External Analysis.....	24
Requirements Analysis	25
User Considerations	26
Internal Analysis.....	26
Knowledge Elicitation and Analysis	26
Knowledge Representation.....	28
Knowledge Modelling	31
Design	43
Negoplan	44
Negoplan Description.....	44
Negoplan Notation.....	45
Selection and Modification Rules.....	52
Termination Rules.....	58
Scoring System.....	59

Negoplan Model of the Sick Infant.....	61
Implementation & Installation.....	70
User Testing	70
Usability Goals	70
Testing Location and Equipment	71
User Instructions	71
Questionnaire	72
Testing Results and Implications	73
User Characteristics.....	73
Quantitative and Qualitative Results	74
Discussion.....	76
Knowledge Refinement.....	78
Use.....	79
Maintenance.....	79
Conclusions.....	80
Research Benefits and Limitations	81
Future Considerations	83
References.....	86

Figures

Figure 1. The KADS Methodology.....	23
Figure 2. Library of Cases.....	32
Figure 3i. Initial Representation.....	33
Figure 3ii. Representation 1	34
Figure 3iii. Representation 2.....	35
Figure 3iv. Final Representation	36
Figure 4i. Initial Representation.....	36
Figure 4ii. Representation 1	37

Figure 4iii. Representation 2.....	38
Figure 4iv. Final Representation	38
Figure 5. Generic Model of the Case Management Process	40
Figure 6. Case Management Process for a Viral Intestinal Infection.....	41
Figure 7. Termination of a Viral Intestinal Case.....	42
Figure 8i. Initial Representation and Selection 1	62
Figure 8ii. Modification 1 and Selection 2.....	63
Figure 8iii. Modification 2 and Selection 3.....	64
Figure 8iv. Modification 3 and Selection 4.....	65
Figure 8v. Modification 4 and Selection 5.....	66
Figure 9i. Initial Representation and Selection 1	67
Figure 9ii. Modification 1 and Selection 2.....	68
Figure 9iii. Modification 2 and Termination	69

Appendices

Appendix A: Glossary of Medical Terms	101
Appendix B: Expert Consultations.....	104
Appendix C: Model of a Bacterial Neurological Infection.....	112

Appendix D:	
Model of a Bacterial Intestinal Infection	115
Appendix E:	
Case Management Model of a Bacterial Neurological Infection	118
Appendix F:	
Case Management Model of a Bacterial Intestinal Infection.....	119
Appendix G:	
Case Management Model of a Terminated Bacterial Neurological Infection	121
Appendix H:	
Case Management Model of a Terminated Bacterial Intestinal Infection.	124
Appendix I:	
Load File	127
Appendix J:	
User Procedures File.....	130
Appendix K:	
Customization File	132
Appendix L:	
Knowledge Base for A Viral Intestinal Infection	137
Appendix M:	
Knowledge Base for A Bacterial Neurological Infection	163
Appendix N:	
Knowledge Base for A Bacterial Intestinal Infection.....	191
Appendix O:	
All Possible Paths of Case Management for a Viral Intestinal Infection	297
Appendix P:	
All Possible Paths of Case Management for a Bacterial Neurological Infection	304
Appendix Q:	
All Possible Paths of Case Management for a Bacterial Intestinal Infection.....	315
Appendix R:	
Screen Snapshots of Case Management of a Bacterial Neurological Infection.....	327
Appendix S:	
Screen Snapshots of Case Management of a Bacterial Intestinal Infection	334

Appendix T: Screen Snapshots of a Terminated Case of a Bacterial Neurological.....	340
Appendix U: Screen Snapshots of a Terminated Case of a Bacterial Intestinal Infection.....	345
Appendix V: Patient Simulator Study Background	349
Appendix W: Questionnaire	351
Appendix X: Demographic Profile Of Users.....	355
Appendix Y: Table of Quantitative Results.....	357
Appendix Z: Summary of Quantitative Results.....	359
Appendix AA: Coding Breakdown	364
Appendix AB: Qualitative Results of Testing.....	368
Appendix AC: Screen Snapshots of Negoplan Version 1.1 i.....	374
Appendix AD: Screen Snapshots of Negoplan Version 1.1k.....	379
Appendix AE: Screen Snapshots of Negoplan Version 2.1	384
Appendix AF: Session Logs.....	389

1.0. Introduction

The clinical decision-making process is complex in nature and many approaches have been introduced over time to aid in this process (Anbar, 1983). Most recently, artificial intelligence (A.I.) techniques have emerged as a viable approach to aid in the clinical decision-making process.

Coinciding with the introduction of A.I. into the medical field, has been the introduction of problem-based or case-based learning into the medical education field. Conventional techniques used in medical education such as lectures and seminars have not been providing students with the fundamental skills necessary to practice medicine effectively. Problem-based learning allows students, within small groups, to acquire medical skills and knowledge with the aid of case studies, written resources, and computer technology.

Computer-assisted learning (C.A.L.) has been playing an increasing role in the medical education field, increasingly, through the use of patient simulators. In this study, a knowledge-based patient simulator was developed, based on the premises of restructurable modelling, and was then tested to determine the effectiveness of the system in assessing the diagnostic and treatment skills of medical students. This study involves the continuation of research which was first conducted by Hans Aggarwal (Aggarwal, 1992). Aggarwal's thesis also involved the development of a prototype of a patient simulator using Negoplan, however, her study focused on the analysis and design phases of the prototype.

The methodology used to develop the system was the KADS methodology, a methodology similar to conventional software development methodologies. Originally, KADS was an acronym, however as the methodology has outgrown the meaning of the acronym, KADS is now taken as the proper name for the methodology. Restructurable

modelling is the modelling process that was applied in the analysis phase of the KADS methodology to represent the knowledge. Senior medical students from the University of Ottawa tested the system and provided feedback which was utilized to make changes in iterations of the prototype.

The main benefit that the knowledge-based patient simulator provides is an alternate method of testing students' diagnostic and treatment decision-making abilities. Successful implementation of the system could be expanded into use of the system in other diagnostic decision-making situations as well, such as in production and in manufacturing.

2.0. Background

"Medicine requires from its practitioners the ability to make rapid decisions based on a multitude of parameters and in a very large depository of information. Medical education, at all levels, is aimed at both increasing the informational base and improving the decision-making skills of the medical student, the house officer, and the practicing physician. The computer, which has become the main tool in maintaining updated and accurate informational databases, offers the most effective tool in meeting the current needs of medical education, and in particular it has become the preferred means of acquiring decision-making skills."

Michael Anbar, "The Socratic Teacher", 1983.

Clinical decisions are made using various approaches. It is important to understand how these decisions are made in order to develop an accurate case management model for the knowledge-based patient simulator. Examination of the classical forms of medical instruction and evaluation point to both strengths and weaknesses in the current curriculum. These strengths and weaknesses must be understood to enable the creation of a knowledge-based patient simulator which can build on curriculum strengths in addition to rectifying curriculum weaknesses. The following section will address these issues in more detail.

2.1. Clinical Decision-Making**2.1.1. Clinical Decision-Making Process**

Clinical medicine can be defined as an area of medicine dealing with the observation and treatment of patients (Webster's Dictionary, 1981). Clinical decision-making requires both diagnostic and treatment decisions on the part of the physician. The clinical decision-making situation itself is a complex decision situation, in which the following conditions exist (Radford, 1988):

- uncertainty caused by a lack of complete information;
- an inability to measure the benefits and costs related to a course of action in quantitative terms (therefore some qualitative analysis is required);
- multiple objectives;
- complexity due to the involvement of more than one physician in the resolution of the decision situation.

In a complex decision-making situation such as medical diagnosis, it is not usually possible to obtain an optimal solution. Therefore within the clinical decision-making process, physicians choose a course of action, or a treatment, that seems best based upon the information available. The clinical decision-making process involves the following steps (Anbar, 1983):

- identification of the disorder;
 - prediction of a course of pathophysiological behaviour;
 - application of therapies based on the implied identity between the problem of a given patient and that of other patients who share similar symptoms and signs, and/or diagnoses;
 - determination of the best testing strategy to differentiate among the various diseases that may possess similar manifestations;
 - determination of when to stop gathering information;
-

-
- determination of the course of treatment and the commencement of treatment;
 - determination of the patient's prognosis;
 - provision of follow-up treatment.

At every step of the clinical decision-making process an important decision must be made. Within this process, physicians seek answers to four main questions (Anbar, 1983):

- Is the patient's life endangered given the particular symptoms and signs?
- What immediate intervention is required to prevent a worsening of the condition?
- Based on the symptoms and signs, what is causing the patient's condition?
- What is the best way to handle the clinical problem?

The above questions are answered using varied decision-making approaches as will be discussed in the following section.

2.1.2. Clinical Decision-Making Approaches

There are various approaches that have been suggested and utilized to varying degrees over time to provide answers to physicians' inquiries. These approaches can be most easily classified as numerical and non-numerical.

Numerical approaches that have been employed are (Anbar, 1983):

- **Statistical Approach** - is based upon the evident symptoms, whereby the existence of symptoms can determine the probability of the existence of a specific disease;
 - **Utility-Based Decision Analysis Approach** - involves choosing the alternative with the highest utility of outcome.
-

The most common non-numerical approaches that have been employed are:

- **Expert-Based Clinical Protocols** - involve programming the clinical activities of medical personnel;
- **Clinical Rule-Based Systems** - involves the use of expert systems which provide expertise to the physician;
- **Disease Systematic Association Approach** - is based upon the symptoms whereby physicians identify a group of diseases, choosing the disease that corroborates with the greatest number of symptoms;
- **"Rules of the Game" Approach** - is based upon the symptoms that are present whereby a specific test is performed from which a specific diagnosis is determined.

Statistical and utility-based decision analysis approaches, although theoretically promising, did not meet with much success in the medical field. Physicians find that these approaches are too simplistic for an area as complex as clinical decision-making. Utility-based decision analysis has also proven to be unsuccessful in the medical field as it requires that utilities be expressed in units, and many human factors such as the quality of human life and human suffering are difficult to express in units. In addition, estimation of the probability of the success of a given treatment will differ among physicians, therefore a sensitivity analysis based on probability ranges will result in information which is considered useless (Anbar, 1983).

Non-numerical approaches have enjoyed increased usage in the late 1980's and 1990's, providing a solution to the problems of clinical decision-making in a specific area of diagnosis. These approaches are based upon the formal description of the mental processes of physicians as opposed to being based upon the numerical calculations that are typically used with statistical and formal utility-based decision analysis approaches. The

computerized simulation of numerical approaches requires less memory and computing capacity than the computerized simulation of non-numerical approaches.

2.2. Medical Education and Training

2.2.1. Classical Forms of Instruction

A survey of eight Canadian university medical calendars (University of British Columbia, University of Calgary, University of Ottawa, McMaster University, University of Toronto, University of Western Ontario, McGill University, and Dalhousie University) revealed that the majority of these universities employ similar instructional techniques, specifically, the lecture format and case studies, to varying degrees.

Most medical programs require four years to obtain an undergraduate degree (excluding the additional two years of required non-medical university courses). Within these four years, the first two years involve instruction in medical basics obtained by taking introductory courses.

A typical first and second year program involves taking courses in the following areas:

- cardiovascular;
- respiratory;
- immunology;
- renal;
- haematology;
- musculoskeletal;
- nervous system;
- mind;
- senses;
- gastrointestinal;
- human reproduction;
- endocrinology.

The main purpose of the first and second year courses is to enable students to describe and explain the basic biological concepts underlying "normal" and "abnormal"

states (University of Ottawa Calendar, 1993-1995). The information in these courses is imparted primarily through lectures. This is an enormous amount of information to absorb within two years as many students enter medical programs with only introductory chemistry, physics, and biology courses.

In the third and fourth years of medical school, students are prepared for, and begin, their internships. Preparation for internship involves in-class courses, and clinical rotation taken in surgery, paediatrics, psychiatry, obstetrics, and geriatrics. These courses are taught through the use of lectures, laboratories and clinics. Clerkships (beginning in the third year), involve the continuation of the teaching process and occur within a hospital setting. The fourth year allows students to become a part of a medical team and actually become involved in the diagnostic and treatment process.

2.2.2. Classical Forms of Evaluation

The survey of the eight Canadian university calendars also revealed that the majority of these universities employ very similar evaluative techniques in addition to employing similar instructional techniques.

The first and second years of medical school employ final year-end examinations (consisting of multiple-choice and/or written essay questions), laboratory quizzes, and term papers. Students are tested mainly on their knowledge of medical facts.

Third and fourth year student assessments are done by their individual clinical teachers and through final examinations similar to those given in the first and second years. The first three years of medical school mainly involve the assessment of a student's grasp of medical facts. Only in fourth year are a student's diagnostic and treatment skills tested and evaluated.

2.2.3. Commentary on Medical School Curriculum

Numerous studies have expressed concern for the curriculum of most medical schools (Barrows, 1983). Medical students are presented with an immense amount of information that is most often in lecture format. As a result, there is little time for students to absorb, understand, retain, and therefore effectively use this information. The lecture format and case studies are the main methods of imparting information in the early years of medical school.

Examinations at the end of each semester are course specific, involve intense cramming, and fail to test a student's ability to recall information learned in previous courses. The tests are typically multiple-choice, are often standardized, and mainly assess the recall or recognition of facts. More recently, students have been evaluated on their ability to solve written cases and on their contribution to group seminars.

Medical textbooks are typically organized by disease. The student gets very little diagnostic experience through memorizing medical facts from a textbook in which students are presented with a number of signs and symptoms, and based upon these factors, must diagnose the disease. The student becomes trained in solving the inverse problem, specifically, in knowing the disease name prior to knowing the signs and symptoms of the disease, which is contrary to what physicians are required to do in the clinical context (Warner, 1989).

Both the large amount of information and the curriculum structure limit the development of the intellectual skills involved in clinical reasoning which are essential to the effective practice of medicine. Long-term retention of information is low, and evidence has shown that little information is remembered by the time students are practicing in the clinical context (Barrows, 1983).

2.2.4. An Effective Medical Learning Process

An effective learning process requires four main factors: active participation, individualization, feedback and reinforcement, and individual pacing (Computer-Assisted Learning Workshop, October 1992). The medical learning process provides active participation and individualization in laboratory class settings. However, the lecture format which is so often used fails to provide an effective learning process as it neglects to meet any of the effective learning process requirements.

The necessary skills which should be acquired by a student during their education in preparation for their clinical years are the following (Shakun and Petruk, 1989; Barker, 1988):

- clinical reasoning (problem solving):
 - * data gathering (history, physical, diagnostic);
 - * diagnostic formulation;
 - * patient management;
 - * communicating clinical data;
 - * life support skills;
 - * patient treatment;
- self-directed learning;
- independent thinking skills;
- critical reasoning skills;
- acquisition of a body of essential knowledge;
- teamwork;
- medical information science;
- personal management skills.

Based on the curriculum of the medical schools surveyed, it is evident that students' clinical and critical reasoning skills are not strongly developed by their final year of medical school.

As early as 1982, two national meetings of medical educators (The Macy Conference on the Teaching of the New Biology, and the Conference on Future Directions of Health Professions and Education) resulted in the following recommendations:

- there should be more emphasis on independent study, and
- there should be a greater concentration on problem-solving and problem-based learning in small groups.

Since the above recommendations were made, medical schools have attempted to emphasize a greater amount of independent study and problem-based learning in the final years of study. Problem-based learning occurs in small groups where a tutor facilitates the learning process by guiding students in problem-solving. This method is utilized to some extent in all medical programs examined in the university calendars, through the use of seminar groups and clinics.

Problem-based learning is concerned with both what knowledge is acquired and how this knowledge is applied. It is considered to be a good method to help medical students acquire the necessary medical skills effectively and efficiently as it facilitates the integration of knowledge from numerous disciplines into an organized knowledge base in the student's mind (Bergeron, 1983). Information acquired through active learning about patient problems is recalled more easily once the student is placed in a clinical context, than it is if the information has been acquired from a textbook. Although problem-based learning enables the acquisition of, and the strengthening of students' diagnostic and treatment skills, problem-based learning is not able to test these skills sufficiently. Diagnostic and treatment skills are not tested until the fourth year of a student's medical education, during their internships, and therefore the student does not receive much experience performing these fundamental skills during their education.

2.3. Medical Education and Computers

2.3.1. Current Situation

The use of computers in medicine dates back to the 1950's where medical equipment required processing aided through the use of computers. Computers in the medical field have made great progress and today they play an important role in medical education. Specifically, medical education can be improved through the use of a computer which has the following properties (O'Shea, 1983):

- it can make decisions based on more information than is usable by any other medium;
- it is reactive in the sense that it can be programmed to respond to a student's actions;
- it can control other devices such as speech input and output or graphical displays, which are very useful in a field as complex as medicine;
- it is not designed to agree with any specific educational theory;
- it allows the student to make mistakes without fear of injuring a human being, thus allowing for a more relaxed learning environment;
- it can allow for the presentation of complex and multiple simulations, which would be virtually impossible to set up otherwise;
- it provides students with exposure to computer technology prior to commencing their practice, thus making them more comfortable with the technology which could become a part of their everyday life in their medical practice.

Numerous instructional and tutorial programs have emerged in the medical field. These programs fall under the domain of computer-assisted learning (C.A.L.) in which computers have proven to play a useful role. Within the realm of C.A.L., simulation is a method of instruction which is becoming more popular in medicine. Both subjects will be discussed in more detail below.

2.3.2. Computer-Assisted Learning

C.A.L. can be defined as a domain that encompasses any activity in which a computer is used to augment (or initiate) a learning or training process (Barker and Yeates, 1985). There are both benefits and limitations with C.A.L. The most evident benefits are: interactive learning, immediate feedback, self-pacing, self-assessment, good simulation of real-life situations, and optimal utilization of expertise. The main drawbacks are: absence of human contact and the inability of the computer to simulate personal interaction between the physician and the patient.

C.A.L. has become a successful area of research but has yet to become a universally accepted teaching tool (Bergeron, 1989; Kruse, 1989; Levy, 1989). The main reasons for the lack of acceptance are (Bergeron, 1989):

- the typically high expenses resulting from the costs of hardware, support staff and maintenance;
- the lack of institutional applicability of particular C.A.L. applications, for example, the poor transfer of technology from university or government research to private industry;
- the inherent difficulties involved with evaluating C.A.L.

An additional reason suggested by Murray (1985) is that early C.A.L. systems claimed high diagnostic accuracy which could not be matched in clinical practice. This was due to the fact that the performance of the system was assessed by diagnosing the same patients whose data were used to develop the system. These circumstances created bias in favour of the system.

When C.A.L. is used as part of the medical education process, and is not used as a substitute for a student's internship, it can become an effective teaching tool for medical students. An inanimate object such as a computer cannot provide training in the

development of physician-patient relationship skills, nor can it aid in the development of teamwork skills. These personal skills are better developed during the student's internship.

There are seven possible modes in C.A.L: problem solving, drill and practice, inquiry, gaming, tutorial, dialogue, and simulation (Barker and Yeates, 1985). This study deals with the simulation mode in C.A.L. as it has been shown to be very effective in medical education (Barnett et al, 1986; Fishwick and Modjeski, 1991; Kohout et al.,1992).

2.3.3. Simulation

Simulation is a method of analyzing a problem situation by creating a model of the situation that can then be manipulated by trial-and-error methods (Fishwick, 1991). Patient simulators can be defined as a representation of a clinical situation in which an individual must assess, analyze and evaluate the patient's response to therapy (Assmann, 1979). Patient simulators are used to assess various components of clinical competence, and to assess some or all of the following: problem-solving skills, clinical judgment, patient management skills, and medical knowledge. Knowledge-based simulation is the application of knowledge-based methods within artificial intelligence to the field of computer simulation (Fishwick, 1991). Patient simulators possess the following common characteristics (Kruse, 1989):

- the patient simulation is initiated by the type of information a patient gives a practitioner;
 - the patient simulation requires a series of sequential, interdependent decisions representative of the stages of assessment and patient management;
 - once data is obtained or a decision is made, it is impossible for the learner to retract that data or decision;
-

- the learner must be able to obtain, in realistic form, information about the results of decisions, especially those which form the basis of subsequent action;
- the patient simulation is structured to allow for variation in both the medical approaches and the patient's response.

Patient simulators may be either linear or branching in format (Kruse, 1989). The linear format forces the user to take an optimal path, while the branching format allows for varied approaches to patient management as the simulation progresses. In addition, patient simulators can be used for either instruction or evaluation. Instructional simulations provide corrective feedback and evaluative simulations provide consequential feedback (Kruse, 1989).

Patient simulators have not gained a great deal of acceptance in the medical field. There are some significant problems specific to patient simulation systems that have not yet been overcome which are hindering this acceptance, namely:

- lack of knowledge of the learning process;
 - non-adaptive simulator strategies;
 - questionable transferability;
 - unrealistic models (Widman, 1989);
 - difficulty in reasoning about time-varying phenomena (Widman, 1989);
 - poor customization;
 - lack of intuitive user interfaces (Bergeron, 1989);
 - provision of only situation-specific feedback;
 - simulators have a limited capacity to analyze the student's judgment and provide feedback regarding their approach to the problem (Wigton, 1986).
-

Although there are inherent disadvantages in using patient simulators, there are also numerous advantages, namely:

- students have access to conditions which may not be routinely encountered in the clinical setting;
- there is no risk to the actual patient;
- they can provide realistic scenarios;
- they provide immediate feedback which enhances learning;
- they can maintain performance scores;
- simulations can be used repeatedly.

The above advantages indicate that within the medical education field, patient simulators have the potential to play a strong role in the medical learning process.

3.0. Literature Review

"There is an increasing concern that the curricula of many medical schools put too heavy an emphasis on memorization of facts and too little stress on problem solving of self-directed study skills necessary for the practice of medicine."

Howard Barrows, "Problem-Based Self-Directed Learning", 1983.

The above thoughts have been echoed by researchers, professors, physicians, and many other individuals in the medical profession. Medical schools in Canada have been attempting to integrate self-directed and problem-based learning with their particular curriculum. The medical calendar for the University of Ottawa (1993-1995) describes the medical program as "placing emphasis on self-learning, assimilating principles and facts in a multidisciplinary fashion, within the context of clinical problems."

Problem-based learning can involve the use of written material, such as journal articles and textbooks; it can involve case studies; and finally it can involve the use of automated tools such as decision support systems and knowledge-based systems.

The field of medical informatics emerged in the 1950's (Blum and Semmel, 1991). In the late 1950's and early 1960's, research in the field consisted mainly of data applications such as signal and image processing. In the late 1960's and early 1970's, medical informatics evolved into information-oriented applications such as patient management systems, which proved to be useful in medical education. In the 1980's and the early 1990's, knowledge applications were introduced to the field of medical informatics, applications of artificial intelligence in medical education.

C.A.L. is an area which involves both information and knowledge applications, and has evolved from rigid computer-oriented approaches to more learner-oriented approaches. As early as 1970, dialogue systems were introduced into the field of C.A.L. (Carbonnell, 1989). These systems would ask the student questions while the student would select an answer from a small set of possible answers. Carbonnell created the first such system, SCHOLAR in 1970, which was used to review a student's knowledge of the geography of South America in a question and answer format.

Problem-solving systems emerged in the early 1970's (Barker and Yeates, 1985), and were based on the hypothesis that the skills used in writing a computer program would aid in the development of general problem-solving skills. Papert developed one of the first programming systems called L.O.G.O., which assisted students in writing small programs.

Mathematical models of learning were introduced in the mid-1970's (Barker and Yeates, 1985). These models attempted to define theories of learning and then to develop computer programs which would apply these theories.

Linear programs first appeared in the late 1970's (Last, 1979). These programs presented a frame to a student within which the student filled in spaces and was immediately informed whether she was right or wrong. The program then moved on to the next frame and continued to provide feedback.

Branching programs and simulation approaches also both emerged in the late 1970's as alternatives in C.A.L. Branching programs allowed a student to respond to a question, and alternate answers were either more acceptable or less acceptable, rather than being correct or incorrect. In addition, these systems were able to provide corrective feedback, and were also adaptive to student responses. CALCHEM, a program created by Ayscough in 1977, tested students on their chemistry knowledge, allowing for slight variations in student responses.

The development of dialogue systems, problem-solving systems, mathematical models of learning, linear programs, and branching programs, led to the development of unique concepts in C.A.L., such as: question and answer formats, frames, alternative answers, and corrective feedback, which have been adopted by many simulation approaches.

Simulation approaches, emerging in 1977, have proven to be one of the most widely used techniques of C.A.L. (O'Shea, 1983). These programs model a system, allowing a student to study the system's behaviour to gain insight into the relationship between different system components, and to gain insight into the system's reaction to stimuli. Computer simulation of medical problems holds great promise in teaching medical

diagnosis and treatment skills. Patient simulators measure clinical competence, which deals with the ability to identify, resolve and manage patient problems, and measure clinical judgment. Important components to include in the design of patient simulation systems are (Tait, Bachman and Edmonds, 1989): realism, scoring facilities, a time scale, ease of use, and a restart capability.

Eight fundamental skills that a student should possess upon completion of formal undergraduate medical training have been defined (Shakun and Petruk, 1989; Barker, 1985), one of which is clinical reasoning, namely, diagnostic formulation and patient treatment. Both skills can be strengthened through the use of patient simulators.

Difficulty in evaluating patient simulators creates some doubt as to the validity and reliability of these systems. Recently, however, a growing amount of research has been conducted in the area of validation of patient simulators. Specific criteria that should be met in the evaluation of these systems are the following (Kruse, 1989; and Miller, 1985):

- content accuracy and consistency;
- appropriateness to the target audience;
- realistic complications and consequences;
- content reflection of the author's clinical and academic expertise;
- user interaction.

The evaluation process must be thorough to ensure the validity and reliability of the patient simulator, thus increasing the acceptance level of these systems.

Patient simulators have been developed to serve many different purposes in medicine. Internist-1 (Miller, 1986) is one of the earliest patient simulators. This system is primarily used to provide diagnostic assistance in the domain of internal medicine. A

more recent manifestation of Internist, called Q.M.R. (Quick Medical Reference), uses the Internist database to generate simulated patients with internal medical problems (Parker and Miller, 1989).

Patient Simulator II (Knowledge House, 1989) is a software package in which the student is presented with a patient and follows the usual case management process in diagnosing the illness and treating the patient. An expert is available within the system for consultation and provides the correct diagnosis and treatment at the end of the case. Patient Simulator II simulates all types of diseases.

G.E.R. (Glomerulonephritis Educational Program) was developed as a simulator of clinical cases of nephritis (inflammation of the kidney) for utilization in medical education (Sigulem et al., 1989). The student is involved in consultations with the computer where the student solves problems (or cases) and is given a score at the termination of each case.

DDxTx (Dental Diagnosis and Treatment Project) was developed to teach the clinical decision-making skills of diagnosis and treatment planning to dental students (Johnson, 1989). The DDxTx project consists of interactive videodisk patient simulations and a management system. Students are then presented with a simulated case that they must solve.

Finally, SIMUL (Champetier De Ribes, 1989) is a patient simulator that offers a set of cases belonging to the same domain. The student is able to interact with the computer through a question and answer interaction format.

The above examples of different patient simulators are just a selection of what actually exists in medical education. It is evident that very different patient simulators are available in diverse areas, and each have varying capabilities, such as graphics capabilities,

natural language interfaces, and scoring functions. However, there are still not many patient simulators in medical education.

The literature review indicates that although the area of medical informatics dates from the 1950's, widespread acceptance of knowledge-based systems in medicine, such as patient simulators, has not yet been achieved. These systems offer many important benefits to the medical education process, specifically, strengthening diagnostic formulation and patient management skills. The opinion is commonly held that patient simulators provide limited feedback, are non-adaptive and have a poor user interface. Therefore the valid and reliable evaluation and testing of patient simulation systems is necessary to ensure an increased acceptance and use of these systems in the future.

4.0. Research Opportunity

A research opportunity exists to develop and test a knowledge-based patient simulator. This opportunity involves:

- i) determining whether restructurable modelling is a viable approach to simulating a sequential decision-making process such as medical decision-making and;
- ii) determining how effective the implementation of restructurable modelling in a computer simulated format is, in testing and assessing the diagnostic and treatment skills of medical students.

5.0. Prototype Development

5.1. Scope

In pursuing the above research opportunity, two specific questions must be answered. First, to determine the viability of the system, can restructurable modelling be used to simulate a patient's condition and behaviour in a case-oriented format? Second, to determine the effectiveness of the system, if restructurable modelling can be used, then is

this type of modelling of the behaviour and condition of a patient useful in testing the diagnostic and treatment skills of medical students?

The knowledge-based patient simulator simulates a patient's condition in an effort to test the user's diagnostic and treatment skills. The patient simulator begins with a written description of the patient's symptoms, following which the medical student (the user) is presented with an initial list of possible actions from which she selects an action, for example, perform a test or exam and/or examine the patient's history. From this information the student continues through the case, selecting actions and evaluating outcomes until she makes the diagnosis or is terminated. At this time she is informed of how successful her diagnosis is, based on a scoring system. The participants in the study are the researcher, the medical students and a physician. Knowledge was elicited from both the medical students, and the physician to construct the knowledge base. The medical students were tested on the system and provided feedback at each iteration of the prototype.

5.2. Feasibility

When examining the feasibility of developing the patient simulator, one must examine the anticipated payoff, need, availability of expertise, existence of a problem and adequacy of resources. The anticipated payoff from the development of the patient simulator is to provide an alternate method of testing the diagnostic and treatment skills of medical students. As was indicated in the literature review, there is a need for better testing methods in medical education. Fortunately, the required expertise both medically and technically was available to successfully develop the patient simulator. A physician was available to verify the medical knowledge and the researcher possessed the necessary experience with Negoplan to build the patient simulator. Development of the patient

simulator fulfills an opportunity rather than solves a specific problem. Resources were more than adequate to enable the completion of the scope of this system.

5.3. Methodology

The methodology used in developing the knowledge-based patient simulator was the KADS methodology (Hickman et al., 1989). KADS, although once an acronym, is now taken as the literal name for the methodology. KADS was developed in the late 1980s and resembles conventional software development methodologies in that it involves stages, phases, and activities. It differs from conventional software development methodologies in that it focuses on the unique characteristics of knowledge-based systems, and problems inherent in their development.

The KADS methodology consists of the following phases: analysis, design, implementation, installation, use, maintenance, and knowledge refinement. Refer to **Figure 1** for a model showing the phases of the KADS methodology, what the input and output are from each phase, and how the phases are related.

Figure 1. The KADS Methodology

Each phase is defined in terms of the activities occurring in that phase, in terms of the inputs into the phase and in terms of the output that is produced. The analysis, design and knowledge refinement phases differ most drastically from conventional software development methodologies, while the remaining phases are very similar.

This study focuses on five phases of the KADS methodology: analysis, design, implementation, installation and knowledge refinement. The implementation and installation phases were collapsed into one phase as both phases involved much of the same activities within the scope of the study. Time constraints do not permit the completion of the use and maintenance phases in the development of the patient simulator. In the analysis and design phases, the viability of our approach to simulating the behaviour and condition of a patient in a case management format will be shown. During the implementation/installation phase the patient simulator was tested by students to examine its

usefulness within the realm of medical education through user testing. **Appendix A** contains a glossary of some of the more complicated medical terms presented within the methodology section.

5.3.1. Analysis

The analysis phase is the critical phase within the KADS methodology in the development of the knowledge base (Hickman et al., 1989). The main purpose of the analysis phase was to determine whether restructurable modelling was a suitable method of simulating a patient's condition and behaviour. The analysis phase consisted of two streams of activity: external analysis and internal analysis. The external and internal streams were conducted simultaneously. External analysis was similar to requirements analysis, whereby users' requirements and the constraints imposed by the working environment were determined. Internal analysis involved knowledge elicitation and analysis, knowledge representation, and knowledge modelling (Hickman et al., 1989).

5.3.1.1. External Analysis

Purpose

The main purpose that the knowledge-based patient simulator served was to test the diagnostic and treatment skills of medical students. Therefore, a student's knowledge level and the application of that knowledge were being tested. The system also attempted to serve the following purposes:

- augmentation of conventional medical teaching methods;
 - acceleration of the learning process;
 - provision of individualized instruction;
-

- provision of cost-effective instruction;
- provision of on-demand instruction;
- allowing of medical students to become acquainted with patient management problems early in their education process.

Requirements Analysis

Based on the evaluation factors observed in previous studies, the researcher ensured the fulfillment of the following requirements:

- knowledge accuracy;
- knowledge completeness and consistency based upon the defined domain;
- well-defined domain of expertise;
- eliminated bias;
- simulation captures reality in that the disease evolves, for example, events in disease evolution occur irregularly and unexpectedly (Levy, 1989);
- constant change of patient status as the result of therapy that may be effective, neutral, or even harmful (Levy, 1989);
- representativeness of a typical diagnostic and treatment scenario;
- interaction with the student;

These factors were examined throughout the development of the prototype and existed at various levels during this time. The final prototype had to meet each requirement sufficiently to be deemed acceptable.

User Considerations

The first important consideration was the computer literacy level of the students tested. The majority of the students were computer literate, having used C.A.L. techniques during their education process (S. Rubin, December 1992). A small proportion of the students had no experience with C.A.L. techniques.

An additional consideration was the lack of familiarization of the user group with many of the concepts involved in the study such as: simulations, restructurable modelling, and the KADS methodology. The concepts to which the students were exposed were simplified and pared down to essential detail, promoting the most efficient testing of the prototype possible.

5.3.1.2. Internal Analysis

Knowledge Elicitation and Analysis

The medical cases developed in this study require management of a particular infection from a group of infections in an infant (three months - two years). The cases existing within the patient simulator are: a viral intestinal infection, a bacterial neurological infection, and a bacterial intestinal infection. An infant was chosen as the patient, for within infant diagnosis, it is less likely that complicating factors will arise, such as multiple conditions occurring simultaneously.

Knowledge elicitation can be defined as knowledge acquisition of a proactive nature, usually accomplished by interviewing one or a number of domain experts using one or a number of semi-formal elicitation techniques (Hickman et al., 1989).

Knowledge was elicited from two main sources: a physician and the medical literature. Medical articles and texts were consulted to aid in the development of a model of

case management for each infection. Familiarity with both medical terminology and the case management process by the researcher allowed for more efficient consultations with the physician. Once a basic understanding of each infection and its structure within case management was achieved, the physician was presented with the tentative model in an unstructured interview format during which he provided suggestions and feedback. The researcher's intent during the interviews was to increase the depth of knowledge for each infection. The corrected models are shown with the detailed descriptions of the meetings with the physician in **Appendix B**.

The knowledge elicitation process was conducted in five meetings. The first meeting on December 18th, 1992, served mainly as an opportunity for the researcher and the expert (the physician) to: come to a common understanding of the research opportunity, discuss the scope of the thesis, determine the student testing format, and discuss the expert's availability.

During the second meeting on February 16th, 1993, the physician was led through a demonstration of the patient simulator that showed the case management of a viral intestinal infection. The knowledge base was developed from knowledge that was previously obtained by H. Aggarwal from Dr. Rubin for her thesis (Aggarwal, 1992). The purpose of the meeting was to have the physician approve the general design of the patient simulator, namely, the graphical user interface, before developing new knowledge bases. It was determined that a bacterial neurological infection was to be the next case to be developed as intestinal and neurological infections have very similar symptoms, thus providing a greater challenge to students during the management of the case.

The third meeting, occurring on March 30th, 1993, offered the researcher the opportunity to obtain feedback about the written model of a bacterial neurological infection

before the knowledge was encoded. The physician provided suggestions and feedback, preparing the researcher for the development of the knowledge base. It was also determined that the final case to be developed within the scope of this study would be a case of a bacterial intestinal infection. The purpose of developing a knowledge base for a bacterial intestinal infection was to deepen the intestinal infection portion of the knowledge base.

During the fourth meeting on May 3rd, 1993, the physician was presented with the comments and suggestions from the first and second testing sessions. As some suggestions required medical knowledge to determine if they were necessary and/or feasible, the physician was able to provide this information. In addition, the physician viewed the patient simulator running a case of an infant with a viral neurological infection after which he provided suggestions for improvement.

The fifth meeting on June 8th, 1993, offered the researcher the opportunity to verify the model of a bacterial intestinal infection. This model proved to be more complex than the previous models and therefore required many iterations.

Knowledge Representation

In the internal analysis phase, knowledge was represented using a modelling process called restructurable modelling (Kersten et al., 1991). The following formal account of restructurable modelling is found in more detail in Kersten, MacDonald, Rubin and Szpakowicz (1993).

Restructurable modelling is a hierarchical modular formalism implemented in Negoplan, a system developed for the modelling and the simulation of negotiation processes. Three interacting entities are distinguished: the simulated agent *a*, the other

participating agent o , and the environment e . The entities find themselves in a situation that describes the world perceived by agent a at a particular moment t in the simulation.

The situation of agent a consists of the agent's structure (a hierarchical representation) and the selected state s_{at} . The situation of the remaining entities is given by the states of the participating agent s_{oT} and by the states of the environment s_{eT} at all moments $T = 1, 2, \dots, t$. A state is a collection of assertions about the entity.

The following four-tuple represents the state of the world at moment t :

$$\langle s_{at}, \{s_{oT}\}, \{s_{eT}\}, D_t \rangle$$

where: s_{at} is the state of a , $\{s_{oT}\}$ is the set of states of o , $T \leq t$; $\{s_{eT}\}$ is the set of states of e , $T \leq t$; and D_t is a hierarchical representation of a at moment t .

The initial structure D_1 of agent a is given *a priori*. The subsequent representations are as follows:

$$p(s_{at}, \{s_{oT}\}, \{s_{eT}\}, C, D_t) = D_{t+1}$$

where: $T = 1, 2, \dots, t$; p is a transformation between representations; and C is a set of all potential components of each D_t .

The representation D_t may be turned into more than one state of agent a , that is, there is a transformation

$$F_a(D_t) = \{s_{atj}\}$$

where F_a transforms D_t into a set of admissible states of a . If the set $\{s_{atj}\}$ has more than one element, the choice of a state is required. This may be done by the user. A choice mechanism may also be given *a priori*, as

$$G_a(\{s_{atj}\}) = s_{at}.$$

The states of the agent o and the environment e are constructed as follows:

$$\begin{aligned} f_o(s_{at}, \{s_{oT}\}, \{s_{eT}\}) &= s_{ot+1} \\ f_e(s_{at}, \{s_{oT}\}, \{s_{eT}\}) &= s_{et+1} \end{aligned}$$

where $T = 1, 2, \dots, t$.

Movement from moment t to $t+1$ involves a transformation of the representation of agent a . Within one step, however, extension of the state is possible. If this is the case then the state s_{at} is determined in two phases. First, some of the elements s'_{at} of the state are constructed from representation D_t , next, the following formula is used:

$$f_a(s'_{at}, \{s_{oT}\}, \{s_{eT}\}) = s_{at}.$$

The passage of time may be represented in two ways. One is to associate time with a transformation of representation D . This reflects the agent's (a) subjective perception of time. Another possibility is to associate time with the environment, for example, introduce time as an element of state s_e .

Stated less formally, restructurable modelling involves the development of a representation of a problem. The problem is represented in terms of a hierarchical structure consisting of goals, subgoals and facts. The interrelationships and interdependencies are defined by the logical implication between goals and subgoals. The hierarchical structure is then formulated as a set of production rules consisting of predicates (representing goals, subgoals and facts) and linked by "and", "or", "not", and "if then" connectives. Predicates may have parameters (numerical or symbolic) whose values can be computed.

Clinical decisions are complex in nature. As the student works through a medical case, restructurable modelling dynamically represents the implications of the clinical decisions involved in case management. As new information becomes known and results emerge from actions selected by the student, the model is further modified and a new representation emerges. Therefore, the decision problem evolves during the decision process. This process is represented with metarules that relate information obtained from the student with evaluated elements of the representation of the patient.

Knowledge Modelling

There are two main model types that were created and utilized in the development of the patient simulator: the model of a sick infant and the model of the case management process. The first model type, the model of a sick infant, shows the change in the representation of the sick infant (through restructurable modelling) based upon the case management actions chosen by the student. These models are useful in providing a general view of the different representations of a specific illness of an infant at specific points in time.

The second model type is a model of the case management process. This model provides a view of the steps that the student takes in managing the case and is the model which is used to build the knowledge base. This model type will be described in more detail following the ensuing discussion of the model of the sick infant.

Figures 2, 3 and 4 are models of a sick infant at different phases or representations of the infection. Figure 2 shows the library of cases (initial representations) which have been implemented in Negoplan. The initial representation for each case specifies the illness (intestinal or neurological), the strain (viral or bacterial), and the visible symptoms.

Figure 2. Library of Cases

Figures 3i - 3iv show generic models of a sick infant based on the three cases developed within the patient simulator. As the particular actions in case management are generic, and the predicates are given a range of parameters that are shown within the parameter key, the case could be any one of the cases specified within the library of cases.

Figure 3i depicts the initial representation for any one of the three infections in the knowledge base: viral intestinal, bacterial neurological, or bacterial intestinal. The visible symptoms are the same for each infection.

Figure 3i. Initial Representation

Figure 3ii depicts the first representation of the patient, specifically, the patient's history and the results from the patient's general exam. These two components are vital information for the physician at an early stage in the management of a case.

Parameter Key		
a = Intestinal or Neurological	h = Normal or Abnormal	o = True or False
b = Viral or Bacterial	i = Low or Normal or High	p = True or False
c = True or False	j = Low or Normal or High	q = 0 - 15 Days
d = 0 - 24 Months	k = Normal or Abnormal	r = Change or No change
e = Normal or Abnormal	l = 0 - 20%	s = Similar Symptoms or No Similar Symptoms
f = 37 - 40 °C	m = Equal or Unequal	t = Normal or Abnormal
g = Ok or Tight	n = True or False	u = True or False

Figure 3ii. Representation 1

Figure 3iii is the second representation of the patient during which general tests are conducted, specifically, a blood test and a urine test.

Parameter Key		
a = Intestinal or Neurological	w = Normal or Abnormal	z = Present or Absent
b = Viral or Bacterial	x = Normal or Abnormal	aa = Present or Absent
v = Normal or Abnormal	y = Elevated or Not Elevated	ab = Present or Absent

Figure 3iii. Representation 2

Figure 3iv shows the final representation of the patient, with the addition of specific tests. This complete representation provides enough information to the student for the diagnosis of the infection.

Parameter Key

a = Intestinal or Neurological	ad = Present or Absent	ag = Increase or Decrease
b = Viral or Bacterial	ae = Present or Absent	ah = Increase or Decrease
ac = Present or Absent	af = Present or Absent	ai = Positive or Negative

3iv. Final Representation

Figures 4i - 4iv show representations of an infant with a viral intestinal infection. Figure 4i shows the initial representation of an infant with a viral intestinal infection.

4i. Initial Representation

Figure 4ii shows the second representation of the patient, specifically, the patient's history and the results of the general exam. The patient history indicates nothing out of the ordinary. The general exam shows that the patient's condition is normal with the exception of: a dry mouth, a fever, and a loss of weight of eight percent.

Figure 4ii. Representation 1

Figure 4iii shows the addition of general tests to further aid in the diagnosis of the infection. The blood test indicates nothing out of the ordinary however the urine test shows that the level of ketones is elevated thus pointing to a possible intestinal infection.

Figure 4iii. Representation 2

Figure 4iv shows the final representation of the patient with the addition of specific tests. The stool test indicates that a virus is present thus enabling the student to conclude with the diagnosis of a viral intestinal infection.

Figure 4iv. Final Representation

Appendices C and D provide models of a bacterial neurological infection and a bacterial intestinal infection respectively.

The second model type is a model of the case management process. **Figures 5, 6 and 7** are models of the case management process. **Figure 5** is a generic model of the case management process while **Figure 6** and **Figure 7** are case management models of a viral intestinal infection.

Figure 5 is a generic model of the case management process. An initial representation of the patient at time zero provides the student with the patient's specific symptoms. The initial representation of the patient and the condition of the patient at time zero are the same as no actions have yet occurred to change the patient's condition. The possible actions represent the different paths that the student can take to manage the case. The list of possible actions at this point in the case would be: conducting a general exam, determining the patient's history, hospitalizing the patient and consulting a specialist.

The student would select one or more actions and would be presented with a list of results of the actions selected such as the results of the general exam. Once she selects one or more actions, a new representation of the patient at time one results. The student is presented with the results of her actions, such as the results of the general exam. The student evaluates these results and selects another action, moving closer to diagnosis. The case management process continues until a successful diagnosis is made or until the case is terminated.

Termination criteria vary depending on the specific infection. The following occurrences will result in a terminated case within the patient simulator: consulting a specialist, hospitalizing the patient, prescribing the wrong interim treatment or not prescribing an interim treatment at all, taking longer than five steps to diagnose the case,

and performing the case management process in the wrong order (for example, conducting general tests before determining the patient's history).

Figure 5. Generic Model of the Case Management Process

Figure 6 is a specific model of the case management process involving the diagnosis of a viral intestinal infection. This scenario is the perfect scenario in that it is the shortest path to the correct diagnosis. The action boxes represent the possible actions that the student can select in managing the case. The check marks are the actions selected by the student. Each heading box represents a step in the case management process. The values shown within the box are the results of the specific actions selected in the previous step. The diagnosis box is the termination of the case.

Figure 6 Case Management Process for a Viral Intestinal Infection

In **Appendix E** is a model of the case management process involving the diagnosis of a bacterial neurological infection. **Appendix F** shows a model of the case management process involving the diagnosis of a bacterial intestinal infection.

In the viral intestinal infection case, the case will terminate if: the infant is hospitalized, the specialist is contacted, a general exam and a patient history are not selected after time two, the wrong interim treatment is selected, the wrong diagnosis is selected, actions are selected in an order that does not follow the case management process, incorrect specific tests are requested and the diagnosis takes too long. **Figure 7** depicts the termination of a viral intestinal case. The student did not follow the correct route in case management of a viral intestinal infection, choosing general tests before learning about the patient's history. This resulted in the termination of the case.

Figure 7. Termination of a Viral Intestinal Case

Appendix G depicts an example of the termination of a bacterial neurological case while **Appendix H** depicts an example of the termination of a bacterial intestinal case. The conditions of termination for both cases are described in the respective appendices.

Completion of the analysis phase has fulfilled the first component of the research opportunity, specifically, determining that restructurable modelling is indeed a viable approach to simulate the case management process. Through the use of the two types of diagrams, the models of the sick infant, and the models of the case management process, it is evident that restructurable modelling shows the changes in a patient's condition as the student progresses through the case management process.

5.3.2. Design

The purpose of the design phase was to design a patient simulator, based on the models developed in the analysis phase, with which the principles of restructurable modelling could be tested. The design phase was a top-down process and began when the requirements had been determined, and the models of the acquired knowledge had been constructed. Output from the external and internal analyses was transferred into physical design specifications or the encoding of the knowledge.

The design section first discusses Negoplan (Kersten, Michalowski, Szpakowicz, and Koperczak, 1991), the shell chosen to implement the knowledge-based system. A detailed description of Negoplan and the shell's particular notation is presented. Development of the viral intestinal knowledge base is analyzed and screen snapshots of the patient simulator running this knowledge base are provided. The examples of the rules from the knowledge base and the snapshots of the patient simulator screens are from the most recent version of the patient simulator (Version Four).

5.3.2.1. Negoplan

Negoplan Description

Negoplan is a knowledge-based shell originally intended for negotiation support and based upon the principles of restructurable modelling, and therefore it allows for changes in the case management process by merging these changes with the model, resulting in a new representation of the patient. Negoplan has applications in many different fields, one of which is medical education. Some of Negoplan's applications are: fraud investigation, robotics, union-management negotiations, disaster management and portfolio management. Negoplan must be directed to specific files to run an application. In using Negoplan to run the patient simulator, it is directed to the medical files that contain: the knowledge base, the load file, the user procedures file, and the customization file. A knowledge base file contains all of the metarules for one specific infection. The knowledge bases will be discussed in greater detail in Section 5.3.2.2. The load file contains the rules that define the initial structure of the patient (see **Appendix I** for an example of a load file). The user procedures file defines the globally maintained parameters and sets the initial values for the score and the step in the management of the case (See **Appendix J** for an example of a user procedures file). The customization file contains customized messages for the patient simulator (see **Appendix K** for an example of a customization file). Together, these components, with Negoplan, form the patient simulator.

Negoplan Notation

There are three entities interacting within the patient simulator: the sick patient, the student who plays the role of a physician, and the environment. The environment includes all elements that are external to the patient and the student, such as the scoring system.

Negoplan's modelling tools include: decomposition rules that describe hierarchies of goals and provide a multi-level structure of the agents, response metarules that describe reactions to the diverse elements of the decision situation, and restructuring metarules that model changes in the decision-maker's goals and perspectives.

Each medical case is represented as a diagram called goal representation. The diagram is constructed from node descriptions, each in the form of a decomposition rule. Decomposition rules can be either normal decomposition rules or selective decomposition rules.

Normal decomposition rules represent a structural decomposition of an entity into subentities (Szpakowicz and Kersten, 1993).

goal <- subgoal1 & ... & subgoal_n. (Decomposition Rule Format)

The following example shows the decomposition of visible symptoms into diarrhea and vomiting.

visible_symptoms <- diarrhea (0) & vomiting (0). (Example)

Decomposition of a goal results in subgoals. Goals and subgoals are written as predicates. The example below shows the predicate name which indicates the nature of the goal. $X_1, \dots, X_n$ are parameters representing details.

predicate_name ($x_1, \dots, x_n$).

(Predicate Format)

The following example is a predicate from the knowledge base in the patient simulator. Some predicates that represent symptoms have parameters that describe attributes of an organ or elements of the patient's history. They are denoted in the examples by parameter names with two capital letters. For example, irritability is a symptom of the patient and IR describes the level of irritability of the patient that may be low, normal or high. The value of a parameter is supplied by the procedure `get_value1` (Symptom, XX) where XX is the parameter's name.

irritability (IR) + `get_value1`(irritability, IR). (Example with a procedure call)

Selective decomposition rules allow the user to construct the problem representation interactively. The user can choose from a number of cases stored collectively as a family of related cases. Problems can also be parameterized and the parameter values computed, or interactively acquired from the user by those procedures such as `get_value1`. Within the knowledge base, the selective decomposition rules represent the three infections. These rules allow the instructor to construct the problem representation by choosing one of the cases stored within the family of cases.

$goal \leftarrow [subgoal_1, \dots, subgoal_n].$ (Selective Decomposition Rule Format)

The user enters a dialogue to indicate subgoals to be retained. After a dialogue in which subgoals $i_1, \dots, i_k$ ($k \leq n$) are selected, the rule is treated as if it were:

$goal \leftarrow subgoal_{i_1} \& \dots \& subgoal_{i_k}.$ (Selective Decomposition Rule Format)

The following example is a selective decomposition rule from the knowledge base that specifies that the infant has at most two infected organs.

$sick_infant \leftarrow [intestinal_system, neurological_system].$ (Example)

Predicates that are assigned to one of the three entities and are given a logical value are called metafacts. A metafact has determined values for its parameters and represents an element of the state of the problem in Negoplan.

entity: predicate_name($x_1^*, \dots, x_n^*$) ::= value (Metafact Format)
 where x_i^* is the value of parameter x_i .

The following example is a metafact from the knowledge base which shows that one of the symptoms of the sick infant is refusal to eat.

$sick_infant: refusal_to_eat ::= true.$ (Example)

Metafacts trigger the participant's reactions modelled by response metarules. Metarules add or remove metafacts in the current representation of the state of the problem. The dynamic aspects of decision-making and simulation are represented in Negoplan by metarules of four kinds: selection metarules, response metarules, modification metarules, and termination metarules.

A selection metarule is a type of a response metarule and it allows the user to interactively tailor responses to her current objectives.

```
{ read_param( modified, x* ) } &                (Selection Metarule Format Example)
  entity: predicate(parameter) ::= true &
```

```
==>
```

```
select (action1(y*), action2(y*), action3(y*))
  where x* is the value of the previous step number
  where y* is the value of the current step number.
```

The following selection metarule shows that the student has previously selected patient history at time 1 and therefore the remaining choices from which she will make a further selection, or selections, at time 2 are: general tests, a general exam, contacting the specialist, and hospitalization.

```
{ read_param( modified, 1 ) } &                (Example)
  student : 'patient history'(1) ::= true &
  student : 'general exam'(1) ::= false
```

```
==>
```

```
select ( 'general tests'(2), 'general exam'(2), 'contact specialist'(2),
  hospitalization(2) ).
```

Response metarules indicate relationships between the interacting entities (the patient, the student, and the environment).

entity₁: predicate₁ ::= true & (Response Metarule Format Example)
entity₂: predicate₂ ::= true &

==>

entity₂: predicate₃ ::= true.

Response metarules are triggered by metafacts. In the following example there is a relationship between the student and the sick infant. If the student selects a C.s.f. exam as the specific test, and the sick infant's fontanel is tight, then the infant's condition is no longer stable, and becomes critical.

student: csf_exam ::= true & (Example)
sick_infant: fontanel(tight) ::= true.

==>

sick_infant : condition(stable) ::= false &
sick_infant : condition(critical) ::= true.

Modification metarules are used to restructure the current representation of the patient. The modification metarule

entity : choice₂ ::= true (Modification Metarule Format Example)

==>

modify (f₁ <- f₃ & f₄)

causes the rule

$$f_0 \leftarrow f_1 \ \& \ f_2$$

to be replaced with the rule

$$f_0 \leftarrow f_3 \ \& \ f_4.$$

In the patient simulator, a variation of the modification metarule was used and is of the form:

$$f_0 \leftarrow \& \ f_3 \ \& \ f_4.$$

This rule replaces $f_0 \leftarrow f_1 \ \& \ f_2$ with the rule

$$f_0 \leftarrow f_1 \ \& \ f_2 \ \& \ f_3 \ \& \ f_4.$$

The following example is a modification metarule from the knowledge base. The student has selected patient history and therefore the representation of the patient must be restructured, displaying the details of the patient's history.

```
step(1) ::= true &
```

(Example)

```
  student : 'general exam'(1) ::= false &
```

```
  student : 'patient history'(1) ::= true &
```

```
  { write_param( modified, 1 ) }
```

```
==>
```

```
modify ( bacteria( neu ) <-& patient_history,
```

```
  patient_history <- diet( 'no change', 1 ) & family('no similar symptoms', 1)
```

```
  & 'bowel movement'( normal, 1 ) & 'no previous treatment'(1) &
```

'no prosthetics'(1) & 'no chronic infections'(1) & 'length of symptoms'('5 hours', 1)).

Some actions selected in case management result in a termination of the case. Termination metarules make it possible to specify conditions in which termination is appropriate.

entity : predicate ::= true (Termination Metarule Format Example)

==> terminate '
Comment to student.'

The following termination rule shows that the student made the correct diagnosis of a virus of the intestinal tract and provided the correct interim treatment of oral rehydration.

student : 'virus of intestinal tract'(_) ::= true & (Example)

student : 'rehydration oral'(_) ::= true

==>

terminate '

The correct diagnosis: virus of the intestinal tract.

The interim treatment: oral rehydration.

Congratulations' .

Further details on the intricacies of Negoplan are given in Szpakowicz and Kersten (1993), Kersten et al. (1991), and Matwin et al. (1989).

5.3.2.2. Development of the Viral Intestinal Knowledge Base

Selection and Modification Rules

Development of the knowledge base can occur once a model of case management for a specific infection is complete. **Figures 5 and 6** showed examples of models of the case management process. The development of such a model provides the necessary structure and information to allow the medical knowledge to be encoded. Refer to **Appendix L, M, and N** for the full knowledge bases for: the viral intestinal infection, the bacterial neurological infection, and the bacterial intestinal infection respectively. **Appendix O** contains diagrams of all possible paths in the case management of a viral intestinal infection while **Appendices P and Q** contain the same diagrams for all possible paths in the case management of a bacterial neurological infection, and a bacterial intestinal infection respectively. These diagrams were used in testing the patient simulator to ensure that all possible paths were accounted for in the knowledge base.

The following example shows samples of rules from the knowledge base for a viral intestinal infection. The representation of the patient is the initial representation based on the visible symptoms, the step (at time zero) and the score (zero). The percent sign (%) indicates a comment. The initial conditions are specified in the knowledge base as the following:

% ----- Initial Conditions

step(0) ::= true.

score(0) ::= true.

Following the initial conditions, a selection rule occurs. The selection rule provides the categories from which the student can select an action to commence management of the case. At time one, the student can select from four possibilities: perform a general exam, inquire about the patient's history, contact a specialist, and hospitalize the patient. The selection rule is displayed in the example below.

```
% ----- Selection 1
sick_infant : diarrhea(0) ::= true & step(0) ::= true

==>
select ( 'general exam'(1), 'patient history'(1), 'contact specialist'(1),
        hospitalization(1)) &
        step(1) ::= true & step(0) ::= false.
```

Once the student selects a specific action or specific actions, a modification rule occurs to change the representation of the sick infant. The modification rule provides the results of the actions selected, and provides any changes in the condition of the patient. In the example of a viral intestinal infection, if the student selected the patient's history and a general exam through the selection rule, the following modification rule would be fired.

```
% ----- Modifications 1
% ----- Patient History and General Exam Selected
step(1) ::= true &
student : 'general exam'(1) ::= true &
student : 'patient history'(1) ::= true &
{ write_param( modified, 1 ) }
```

 ==>

```

modify ( virus( int ) <-& general_exam & patient_history,
        general_exam <- pulse( high, 1 ) & behaviour( normal, 1 ) & fever( 38, 1 )
        & 'blood pressure'( low, 1 ) & 'head size'( normal, 1 ) & age( '13
        months', 1 ) & 'loss of weight'( 8, ' per cent', 1 ) & fontanel( ok, 1 ) &
        'dry mouth'( 1 ) & skin( normal, 1 ), patient_history <- diet( 'no change' ) &
        family( 'no similar symptoms' ) & 'bowel movement'( normal ) & 'no
        previous treatment' ) .

```

The above rule restructures the representation of the patient in that it adds results from the two selected actions to the current representation. Once the results of the patient's history and the general exam are displayed, a second selection window is displayed. This selection window allows the student to select from a variety of options that vary depending on what processes remain to be completed within the case management process. In the viral intestinal example, since both the patient's history and a general exam have already been selected, the remaining selections are: general tests, contact the specialist, provide an interim treatment and hospitalize the patient. These selections are displayed in the selection rule below:

```

% ----- Selections 2
% ----- both General Tests and Interim Treatment
{ read_param( modified, 1 ) } &
  student : 'general exam'( 1 ) ::= true &
  student : 'patient history'( 1 ) ::= true

```

```

==>
select ( 'general tests'(2), 'contact specialist'(2),
        'interim treatment'(2), hospitalization(2) ) &
        step(1) ::= false & step(2) ::= true .

```

Following the selection of general tests and an interim treatment, a modification rule at time two would be fired. The results of the general tests would be displayed after the patient representation is modified with the following modification metarule:

```

% ----- Tests Requested (General Exam and History Done)
% ----- Interim Treatment requested
        step(2) ::= true &
        student : 'general exam'(1) ::= true &
        student : 'patient history'(1) ::= true &
        student : 'general tests'(2) ::= true &
        { write_param( modified, 2 ) }

==>
modify ( virus( int ) <-& blood_test & urine_test,
        blood_test <- 'red cell'( normal, 2 ) & 'white cell'( normal, 2 ) &
        'cell smear'( normal, 2 ),
        urine_test <- ketones( elevated, 2 ) & 'blood in urine'( absent, 2 ) &
        sugar( absent, 2 ) & proteins( absent, 2 ) ) .

```

Progressing along the shortest route to diagnosis, the student would next select the methods of interim treatment and the specific test or tests, namely, oral rehydration and a stool test. This scenario is displayed in the rule below:

```
% ----- Specific Tests and Interim Treatment requested
{ read_param( modified, 2 ) } &
  student : 'general tests'(2) ::= true &
  student : 'interim treatment'(2) ::= true &
  { existing_metafact( student, 'general exam'(_), true ) } &
  { existing_metafact( student, 'patient history'(_), true ) }

==>
select ( 'specific tests'( stool, 3 ), 'specific tests'('csf exam', 3 ),
        'specific tests'( urine, 3 ), 'specific tests'( 'lumbar puncture', 3 ),
        hospitalization(3), 'rehydration oral'(3),
        'rehydration intravenous'(3), antibiotic(3), 'contact specialist'(3) ) &
step(2) ::= false & step(3) ::= true .
```

The two statements in parentheses invoke external procedures that verify whether the following metafacts exist. The underscore characters between the brackets indicate that the test is done for each value of the parameter.

```
student : 'general_exam'(_), true
student, 'patient history'(_), true.
```

Following the selection of the interim treatment and specific tests, a modification rule at time three will be fired. The firing of this rule will result in a new representation of the patient, providing the student with the results of the stool test and with a change in the visible symptoms. In addition, the new representation will show that the application of an interim treatment alleviated the patient's symptoms.

% ----- Specific Tests and Correct Interim Treatment

```

step(3) ::= true &
student : 'specific tests'( stool, 3 ) ::= true &
student : 'rehydration oral'(3) ::= true &
{ existing_metafact( student, 'general tests'(_) true ) } &
{ write_param( modified, 3 ) }

==>
modify ( virus( int ) <-& visible_symptoms(int, v1) & specific_tests( stool ),
        visible_symptoms(int, v1) <- not diarrhea(3) & not vomiting(3) &
        irritability(neutral, 3 ), specific_tests( stool ) <- blood( absent,3 ) &
        'bacterial culture'( absent, 3 ) & pass( absent, 3 ) & parasites( absent, 3 ) &
        viral( positive, 3 ) ) .

```

Following the shortest route to diagnosis, the student could now make her diagnosis based on the information available to her. She would be provided with a list of possible diagnoses as is seen below:

% ----- Rehydration Oral and Specific Tests (stool) requested

```

{ read_param( modified, 3 ) } &
student : 'rehydration oral'(3) ::= true &
student : 'specific tests'( stool, 3 ) ::= true &
{ existing_metafact( student, 'general tests'(_), true ) }

==>
select ( 'virus of intestinal tract'(4), 'parasite of intestinal tract'(4),
        'virus of neurological tract'(4) ) &
        step(3) ::= false & step(4) ::= true .

```

Once the student selects the correct diagnosis of a virus of the intestinal tract, the case is terminated. The following rule is a sample of the termination rule that would be fired once she made the correct diagnosis.

```
% ----- Correct Diagnosis and Treatment
student : 'virus of intestinal tract'(_) ::= true &
student : 'rehydration oral'(_) ::= true

==>
terminate ':
    The correct diagnosis: virus of the intestinal tract.
    The interim treatment: oral rehydration.
    Congratulations' .
```

Termination Rules

There are numerous termination rules existing within each individual knowledge base. Most of the termination rules occur as a result of improper case management and as a result of an incorrect diagnosis. The following termination rule occurred as a result of the student selecting general tests prior to selecting the patient's history which is improper case management of a viral intestinal infection.

```
% ----- No History Requested After Selection 2
step(2) ::= true &
{ \+ existing_metafact( student, 'patient history'(T), true ) }

==>
terminate ':
    You cannot proceed further.
    You must learn the management of the case.'
```

Scoring System

The patient simulator can be run with a scoring system if so desired. At this point in the development phase, a scoring system exists only for the viral intestinal infection. The scoring system is designed to allocate points for each step in case management. The student following the shortest route to diagnosis would receive fifty out of a possible fifty. The following example shows how a score of fifty would be awarded to a student following the shortest route to diagnosis:

In the first evaluation, the student selects a general exam and the patient's history. The student is awarded five points for performing the first step in the management of the case correctly. At time one the score is fifteen out of fifty.

% ----- SCORING SYSTEM

% -----Evaluation 1

step(1) ::= true &

student : 'general exam'(1) ::= true &

student : 'patient history'(1) ::= false

==>

{ read_param(score, S) } & score(S) ::= false & { S1 is S + 15 } &
score(S1) ::= true & { write_param(score, S1) } .

In the second evaluation, the student selects an interim treatment and general tests. This selection increases the score to thirty.

% ----- Evaluation 2

step(2) ::= true &

student : 'general tests'(2) ::= true &

student : 'interim treatment'(2) ::= true

```
==>
{ read_param( score, S ) } & score(S) ::= false & { S2 is S + 15 } &
  score( S2 ) ::= true & { write_param( score, S2 ) } .
```

In the third evaluation, the student selects a stool test as the specific test and oral rehydration as the interim treatment, which increase the score to forty-five.

% ----- Evaluation 3

```
step(3) ::= true &
student : 'specific tests'( stool, 3 ) ::= true &
student : 'rehydration oral'(3) ::= true
```

```
==>
{ read_param( score, S ) } & score(S) ::= false & { S3 is S + 15 } &
  score( S3 ) ::= true & { write_param( score, S3 ) } .
```

The fourth evaluation involves making the correct diagnosis, which is a virus of the intestinal tract. The correct diagnosis results in an additional five points which gives the student a final perfect score of fifty.

% ----- Evaluation 4

```
step(4) ::= true &
student : 'virus of intestinal tract'(4) ::= true
```

==>

```
{ read_param( score, S ) } & score(S) ::= false & { S4 is S + 5 } &  
  score( S4 ) ::= true & { write_param( score, S4 ) } &  
  done('total score is out of 50') ::= true.
```

The longer it takes the student to make a diagnosis, the lower is the final score. Due to time constraints, the viral intestinal knowledge base is the only knowledge base of the three that contains a scoring system. Refer to the viral intestinal knowledge base in **Appendix L** for a list of the evaluation rules used in the scoring system.

5.3.2.3. Negoplan Model of the Sick Infant

Figures 8i - 8v show screen snapshots from the patient simulator running a typical case management scenario using Negoplan Version 2.1g. The scenario demonstrates the shortest path to the diagnosis of a viral intestinal infection and includes the scoring mechanism. The first window (Sick Infant) displays the patient's condition and displays the results of the actions selected by the student. The second window (Student) displays the actions that the student selects. The third window (Environment) displays the scoring system and the step in the case management process. The environment window can be hidden or displayed. In testing situations it is more useful to have the window hidden and to show the score to the student at the termination of the case.

In Figure 8i the student is presented with the initial representation of the patient, and based on the symptoms, makes the first selection to inquire about the patient's history and to perform a general exam as is indicated by the check marks.

Figure 8i. Initial Representation and Selection 1

In Figure 8ii a new representation of the patient occurs as the results of the general exam and the patient's history are displayed. The patient's history indicates nothing out of the ordinary, while the general exam indicates that the infant's blood pressure is low, his pulse is high, and he has had a weight loss of eight percent. The symptoms and the results of the general exam are displayed in the left window. More information is needed before a diagnosis can be made. The student selects general tests and interim treatment from the actions box. The score is fifteen.

Figure 8ii. Modification 1 and Selection 2

In Figure 8iii the representation of the patient changes once again and the results of the general tests are displayed. The test results are normal, with the exception of the level of ketones which is elevated, indicating a possible infection of the intestinal tract. The score is now thirty. The student chooses oral rehydration as the interim treatment and a stool test as the specific test.

Figure 8iii. Modification 2 and Selection 3

After the third modification, the results of the stool test are displayed. It is also evident that the interim treatment has alleviated the infant's symptoms as the diarrhea and the vomiting have disappeared. At this point the student has adequate information to make a diagnosis of a virus of the intestinal tract. The score is forty-five.

Figure 8iv. Modification 3 and Selection 4

The final modification results in a termination of the case as the diagnosis and interim treatment were correct. The final score is a perfect score of fifty. **Appendices R** and **S** contain snapshots of the shortest route to diagnosing a bacterial neurological infection and a bacterial intestinal infection.

The screenshot displays a software interface titled "Options Tracing Control" with a status bar indicating "This is the end of this simulation". The interface is divided into three main sections: "Sick infant", "Student", and "Evaluation".

Sick infant section lists the following attributes:

- cell count(normal: 2)
- fever(50: 1)
- fontanelle(1)
- head size(normal: 1)
- irritability(neutral: 3)
- ketones(elevated: 2)
- parasites(absent: 3)
- poorly absorbed: 3)
- protein(absent: 2)
- pulse(high: 1)
- red cell(normal: 2)
- skin(normal: 1)
- supernatant: 2)
- white cell(normal: 2)
- loss of weight(8, per cent: 1)
- viral(positive: 3)

Below the list, a message states: "Terminated because of:
The correct diagnosis: virus of the intestinal tract
The interim treatment: oral rehydration
Congratulations"

Student section lists the following actions:

- patient history(1)
- general tested(2)
- rehydration oral(3)
- interim treatment(2)
- virus of intestinal tract(4)
- specific test(stool: 3)
- false contact specialist(1)
- hospitalization(1)
- contact specialist(2)
- hospitalization(2)
- specific test(csf exam: 3)
- specific test(urine: 3)
- specific test(lumbar puncture: 3)
- hospitalization(3)
- rehydration intravenous(3)
- antibiotic(3)
- contact specialist(3)
- parasite of intestinal tract(4)
- virus of neurological tract(4)

Evaluation section shows the following results:

```

true stop(4)
score(50)
done(total score is out of 50)

false stop(0)
score(0)
stop(1)
score(15)
  
```

Figure 8v. Modification 4 and Selection 5

Figures 9i - 9iii are examples of the case management of a viral intestinal infection. In this example, the student has managed the case incorrectly, specifically, the student has chosen to conduct general tests before learning about the patient's history which is improper management of the case.

Figure 9i. Initial Representation and Selection 1

The results of the general exam are displayed as are the patient's symptoms. The student's second selection is general tests.

Figure 9ii. Modification 1 and Selection 2

The results of the general tests are not shown as the case has been terminated since the student has not yet examined the patient's history.

Figure 9iii. Modification 2 and Termination

Appendices T and U contain termination snapshots of a bacterial neurological case and of a bacterial intestinal case respectively.

Completion of the design phase has shown that restructurable modelling can be implemented in a computerized simulation environment, representing the behaviour and condition of a patient.

5.3.3. Implementation & Installation

In the KADS methodology, the implementation phase occurs prior to the installation phase. In this study, the implementation and installation of the patient simulator occurred simultaneously for the reason that the system is a prototype and therefore the design specifications were implemented and installed within the same period of time. Specifically, implementation involves setting up the design specifications in a computerized environment while installation involves user testing of the system. Within the scope of this study, the system was being tested, and feedback from the testing sessions resulted in iterative changes of the design specifications. Negoplan was implemented in Prolog and its full version runs on the Apple Macintosh. The patient simulator is currently running on a Macintosh Quadra 800.

Within the implementation and installation section, the following topics are discussed. user testing (determining the usability goals, determining the testing location, specifying the user instructions, development of the questionnaire) and results and implications (discussion of user characteristics and the presentation and discussion of the qualitative and quantitative results).

5.3.3.1. User Testing

Usability Goals

Due to the fact that the patient simulator is a prototype, there were a limited number of specific usability goals defined. If specific goals were not met, the students were asked to provide details on their recommendations which were considered, and if valid, were implemented in the system. The specific usability goals were the following:

- 1) The screen set-up must receive at least a three out of five from all students tested.
-

-
- 2) The simulator speed must receive at least a three out of five from all students tested.
 - 3) The representativeness of a diagnostic and treatment scenario must receive at least a four out of five.

The third usability goal was considered the critical goal at this stage in the study as a consistently unsatisfactory rating of that question would involve starting at the analysis phase again. Usability goals one and two, although important, were issues that could be dealt with during the design and/or the implementation/installation phase. The patient simulator was tested until the usability goals were met. A questionnaire completed by the students at the end of a testing session provided the necessary feedback to determine whether the goals were met.

Testing Location and Equipment

The testing location was the Decision Analysis Lab in the School of Business. This environment was felt to be adequate as it contained the necessary equipment, had enough space for two students to be tested at a time, and allowed for no interruptions during the testing process. A Macintosh Quadra 800 driven by a mouse was used to run the patient simulator. Pens and paper were available for students to use as scrap paper and to write down any comments and/or suggestions. The researcher conducted the test and was available to answer any questions during the testing session.

User Instructions

Each student was provided with a written description of the study titled Patient Simulator Study Background, prior to the commencement of the testing session. Students were tested in pairs to allow for consultation with each another and to allow for a more relaxed environment for feedback. The Patient Simulator Study Background provided the

student with details on: the purpose of the study, the scope of the study, and what the completed prototype would be like, to give the student an idea of what the patient simulator's capabilities would be. In addition, the researcher's name and phone number was provided in case the student had questions, comments, or suggestions at a later date. A copy of the Patient Simulator Study Background is in **Appendix V**.

Verbal instructions were given following the provision of the study background. Students were told that they were free to: consult with each other, ask questions of the researcher, and make comments and/or suggestions at any point throughout the session. The students began the session by looking at a list of symptoms and continued with the case management until termination of the case or until a diagnosis was made. The majority of the students ran the patient simulator three or more times before feeling satisfied that they had thoroughly tested the patient simulator.

Questionnaire

Development of the questionnaire was based upon three similar studies which also involved the development and testing of a patient simulator (Day & Payne, 1987; Lincoln et al., 1991; Koch et al., 1990). **Appendix W** contains the questionnaire used in the testing sessions. The main purpose of the questionnaire was to determine quantitatively whether the requirements specified in the analysis section and the usability goals specified in the implementation/installation section were achieved. The most critical feedback from the students was the qualitative feedback. This was obtained from both verbal and written comments made by the students to the researcher during the testing session. In addition, four demographic questions were asked of the students to ensure that there was some diversity in the characteristics of the student's testing the patient simulator..

The researcher enlisted the aid of a doctoral student in psychology and a graduate student in sociology, both specializing in user testing, in the development of the questionnaire. It was intended to keep the questionnaire simple, and to focus on the verbal feedback and suggestions received during the session.

5.3.3.2. Testing Results and Implications

User Characteristics

When examining the results and the implications of the testing sessions, it is important to examine the characteristics of the students who were testing the system. Cooperation had been obtained from the Faculty of Medicine at the University of Ottawa, prior to the proposal defense that ensured the assistance of students from a senior level paediatric class. In total, twelve students were tested. Four students were tested on each version of the patient simulator. The feedback from each group of students was implemented producing successive and improved versions of the patient simulator. After two separate pairs had tested the system, the feedback was similar enough that further testing of the same version would have been redundant, hence, the suggestions were implemented and four more students tested the next version. The current version of the patient simulator is the fourth version. The fourth version is the culmination of all suggestions made by the students.

A brief demographic profile of all students tested is available in **Appendix X**. The first version of the patient simulator was tested by two business students and two psychology students. It was intended at this point to obtain feedback on the graphical user interface and therefore it was felt that medical knowledge was not required by the testers. The second and third versions of the patient simulator were tested by medical and science

students who were able to provide feedback on the medical feasibility of the patient simulator.

Quantitative and Qualitative Results

The quantitative results are based on the results from the questionnaire and can be seen in **Appendix Y**. A description of the quantitative results is in **Appendix Z** which describes the results for each question in the questionnaire. A coding breakdown for the questionnaire is in **Appendix AA**. The coding breakdown explains the values given to each question in the questionnaire. The qualitative results are based on the student's verbal comments made during the testing session and written comments from the questionnaire after the testing session. **Appendix AB** contains the detailed qualitative results of each testing session.

As discussed in Section 5.3.2.1, the patient simulator is run using a specific version of both Negoplan and the medical files, which changed periodically based on the feedback received by the students. The Negoplan versions that were tested were: Negoplan Version 1.1i, Negoplan Version 1.1k, and Negoplan Version 2.1. The medical files ranged from Medic.One to Medic.Three. The current patient simulator (Version Four) is run with Negoplan Version 2.1g and Medic.Four.

Version one of the patient simulator is run with Negoplan Version 1.1i using Medic One as the knowledge base. In version one, the students found: the screen set-up and the simulator speed to be poor, the patient simulator to be representative of a diagnostic and treatment scenario, and the potential usefulness of the patient simulator to be good. The students were most dissatisfied with the simulator speed, however, felt that in general, the

patient simulator had the potential to be a useful tool in testing their diagnostic and treatment skills. Refer to **Appendix AC** for snapshots of Version One of the patient simulator.

Appendix AD shows Version Two of the patient simulator that incorporated the feedback and suggestions from the first testing session. Version two is run with Negoplan Version 1.1k with Medic.Two as the knowledge base. Version Two had a different screen set-up and an increased speed. Most notably, the messages that the computer displayed to the student were adapted to a medical situation and the knowledge base was modified to make it more efficient and to increase the speed of the simulation. The students found: the screen set up to be good, the simulator speed to be poor, the patient simulator to be highly representative of a diagnostic and treatment scenario, and the potential usefulness of the patient simulator to be good.

Appendix AE shows Version Three of the patient simulator. Version Three is run with Negoplan Version 2.1 with Medic.Three as the knowledge base. The main addition to this version is the pending capability whereby the student is told that tests are pending if they are tests that take more than a day to come back from the lab. The other main addition is the ability of the student to choose their own specific tests as opposed to being provided with the results from the specific tests. The students found: the screen set-up to be good, the simulator speed to be average, the patient simulator to be highly representative of a diagnostic and treatment scenario, and the potential usefulness of the patient simulator to be very good. The main changes in this version occurred to the bacterial neurological knowledge base as it required corrections with some of the medical terminology.

The patient simulator was tested until the usability goals were achieved which occurred at the end of the third testing session. The usability goals once again are:

- 1) The screen set-up must receive at least a three out of five from all students tested.
- 2) The simulator speed must receive at least a three out of five from all students tested.
- 3) The representativeness of a diagnostic and treatment scenario must receive a four out of five or higher from all students tested.

The first usability goal was achieved by the end of the third testing session. The second usability goal was achieved by the end of the second testing session. The third usability goal was achieved by the end of the third testing session. The feedback from the final testing session was implemented into the prototype which resulted in the current version, Version Four, of the patient simulator that is run with Negoplan Version 2.1g with Medic.Four as the knowledge base.

Appendix AF contains copies of the logs of each testing session. The student testing sessions were logged to allow the researcher to observe any patterns or discrepancies when analyzing the qualitative and quantitative feedback from the students

Discussion

In order to fulfill the research opportunity, specifically, to determine whether restructurable modelling can be used to simulate a patient's behaviour and condition, and to determine whether the patient simulator is useful in medical education, the eight requirements which were identified in Section 5.3.1.1 had to be met. These requirements were met as was ensured by the researcher through the use of medical literature, the physician and the testing sessions with the students.

The specific requirements that were met are: knowledge accuracy, knowledge completeness and consistency, well-defined domain of expertise, eliminated bias, simulation captures reality in that the infection evolves, a constant change of patient status, representativeness of a typical diagnostic and treatment scenario, and an interactive environment for the students.

The existence of the first and second requirements was ensured by the researcher, the physician, the students testing the patient simulator, and through the medical literature. The knowledge was obtained from two main sources in the medical literature and one source was always validated against the second source. The two primary sources used were the Merck Manual of Diagnosis and Therapy (1987) and Infectious Infections by Hoeprich (1972). Once the basic structure of the infection had been drawn, the physician verified the accuracy of the knowledge. The students testing the patient simulator also served as a source of validation.

It was ensured that the area of expertise was well-defined by immediately limiting the scope of the thesis to infections in infants. The specific infections chosen to place in the knowledge were: a viral intestinal infection, a bacterial neurological infection, and a bacterial intestinal infection. These infections were both within the realm of expertise of the physician and were also within the realm of knowledge of a senior medical student.

The fourth requirement, elimination of bias, was ensured by having more than one source for the knowledge, specifically both the medical literature and the physician. In addition, and once the knowledge was encoded, the students tested the patient simulator.

The fifth and sixth requirements of the simulation capturing reality by having the infection evolve and having the patient's status change were ensured by the researcher through basing the development of the models upon the premises of restructurable

modelling. Restructurable modelling allowed for changes in the representation of the patient's status and in the evolution of the infection. Once again the physician and the students validated the patient simulator.

The seventh requirement of the representativeness of a typical case management scenario was first ensured by the researcher in that the knowledge was structured following the case management process prior to encoding the knowledge. The physician then verified the structure of the model. The representativeness of the patient simulator was finally evaluated by the students both through the questionnaire and through verbal and written feedback.

The final requirement, specifying the interaction of the patient simulator with the student was first ensured by the researcher during the development of the patient simulator. This requirement was ensured by having the patient simulator prompt the student with questions as was seen in the screen snapshots. The physician evaluated the interactive nature of the patient simulator in his informal evaluations of particular iterations of the prototype while the students' qualitative and quantitative evaluations provided additional assurance.

5.3.4. Knowledge Refinement

The knowledge refinement phase involved changing and amending the knowledge base during the analysis, design, and implementation/installation phases. Knowledge refinement occurred following the receipt of comments and suggestions from the physician and the students who were testing the system.

During the analysis phase, the models of the sick infant for each infection were refined as more knowledge was acquired from medical literature and from the physician.

The models incurred numerous iterations as it was vital that they were accurate prior to the development of the knowledge base. In the design phase, the structure of the knowledge within the knowledge base was sometimes altered to make the patient simulator more efficient. During the implementation/installation phase, the feedback and the suggestions from the students and the physician further contributed to the refinement of the knowledge as corrections were made and knowledge was added to the knowledge base.

5.3.5. Use

In the KADS methodology, the use phase begins when the installation phase is completed. The use phase would primarily involve problem-solving sessions between the patient simulator and the students. Additional iterative changes would be made to the system as it is further tested by the students. This phase was not conducted within the scope of this study. The patient simulator would have to incur further development of the knowledge base and further testing before it could be considered to be a fully functional testing tool.

5.3.6. Maintenance

A large portion of the maintenance of the patient simulator would involve updating the knowledge base. Maintenance would occur during the actual usage of the system, specifically, when the system no longer satisfies the user or when the system's environment changes. This phase was not conducted within the scope of this study as the system is a prototype and incurs frequent changes as it moves towards development into a fully functional system.

6.0. Conclusions

"Computer learning programs are effective learning tools and are a useful addition to traditional teaching methods. Further study is required to assess the effects of computer-aided learning programs in long-term studies of dementia knowledge."

Awbrey, 1985

Medical education and training has been shown to be lacking in certain areas, specifically in the area of testing and evaluating medical students. Computer-assisted testing provides many advantages which typical testing procedures in medical schools fail to provide.

The main purpose of this study was twofold: first, to determine whether restructurable modelling is a viable approach to use to simulate the medical decision-making process; and second, to determine how effective the implementation of restructurable modelling in a computer simulated format is in testing and assessing the diagnostic and treatment skills of medical students.

The KADS methodology was used to provide structure to the development and testing of the patient simulator. During the analysis phase, models showing chronological representations of the sick infant for each infection were created. These models were based on the premises of restructurable modelling. Thus the first component of the research opportunity was shown to be possible, specifically, that restructurable modelling is a viable approach to use in simulating the medical decision-making process.

During the design phase, the models were transferred into a knowledge base. The knowledge base, once completed, allowed for computerized case simulations of an infant's illness. The knowledge base was developed using Negoplan which is a shell based on the premises of restructurable modelling.

The implementation/installation phase allowed for the testing of the patient simulator. Twelve students, comprised of both medical and non-medical students, tested different versions of the patient simulator (four students tested each version). Feedback and suggestions from the students were implemented into each version resulting in the fourth and final (within the scope of this study) version of the patient simulator.

Based on the feedback (both qualitative and quantitative) received from the students, the physician, and the Associate Dean of Medical Education at the University of Ottawa, the patient simulator was determined to be a potentially useful tool in testing and assessing the diagnostic and treatment skills of medical students.

7.0. Research Benefits and Limitations

Due to time constraints, and to the intensity involved in developing and testing the system, the system was initially tested by a small sample of students (twelve) from the University of Ottawa and Carleton University. Since the system is a prototype that will require further development, external validity can be ensured in further studies, once a full-scale working system is created. Thus, this is not felt to be a limitation of this study.

The first limitation occurs as a result of the limited number of cases within the patient simulator. The system does not provide a wide variety of diagnostic situations for students, however, in time this situation can be remedied with the expansion of the system. Moreover, the purpose of this study was to analyze the appropriateness of the approach (restructurable modelling) and its successful implementation. The focus of this study was not to develop multiple knowledge bases for numerous infections.

An additional limitation, also due to time constraints, is that the system was designed, implemented and installed as a prototype and therefore the use and maintenance of the system could not be conducted within the scope of this study.

In contrast to the above limitations, the study provides the following benefits. First, it has been observed that the proposed patient simulator can provide an improved way of teaching the diagnostic process to medical students by allowing students to learn actively by interacting with the system. Current teaching methods have proven to be lacking as students are not attaining the necessary diagnostic and treatment skills until they begin their internship. Further evaluation of the system and its impact on teaching and testing practices is possible once a full-scale version is developed.

A second benefit is the possibility of generalizing the approach used in this study to develop other simulators in various areas requiring diagnosis such as manufacturing, production, and strategic decision-making. Each of these areas requires a structure similar to that of case management in determining a solution to the problem. Therefore studies could be conducted within these areas following closely the format of this study..

A final benefit occurs as a result of the modelling method that was used, specifically, restructurable modelling. Restructurable modelling allows for a dynamic decision-making environment for the student as the patient's condition is always changing. The capability of dynamic modelling provides the system with a unique characteristic that allows for a more realistic simulation, a characteristic not common in many patient simulators currently in existence.

8.0. Future Considerations

Based on the researcher's experiences, feedback from the students and physician, and from the observation of other patient simulators, the following future considerations are presented.

8.1. Future Considerations For the Analysis Phase

Future considerations that would require further work in the analysis phase of the KADS methodology involve expansion of the knowledge base. Specifically, the existing knowledge base must continue to be increased in depth and breadth. The depth of the knowledge base could be increased by eliciting and encoding additional knowledge for the infections currently in the knowledge base. Specifically, more details would have to be obtained about: patient symptoms, patient history, the general exam and tests, and the specific tests. Breadth of the knowledge base could be increased by encoding additional infections. Based on feedback from the physician, the next infection to encode in the knowledge base should be a kidney infection.

A second consideration would be to provide more specifics on each selection within case management. The student could have the option to obtain more detail on any symptom if wanted. For example, details on vomiting could involve consistency, frequency, duration, etc. The patient history could include details on specific medical areas such as cardiopulmonary history and gastrointestinal history. The student could choose which areas of the body she wishes to examine and which tools should be used to do so. Interim treatment could require more specificity, for example, requiring the student to indicate dosages for drugs and rehydration. Specific tests could be divided into lab tests and investigative procedures. Lab tests would also involve x-rays while investigative

procedures would involve further physical examination by the physician or by a specialist. In addition, the student could be told how long the specific test will take and could have the option to not perform the test if it is time consuming. Once the illness is diagnosed, the student could suggest a treatment such as a specific diet, a specific medication, or consultation with a specialist.

8.2. Future Considerations For the Design Phase

Future considerations that would require further work in the design phase of the KADS methodology involve the use of graphics. Certain tests and exams provide visual results in a realistic case management setting. Pictures could be scanned into the computer which would provide the student with visual images of test results. Graphs could be used to show certain aspects of case management such as what the patient's systolic blood pressure is.

A second consideration would be to enhance the current user interface. The interface could include pull-down menus, icons, and graphics.

A third consideration within the design phase is the expansion of the scoring system. Currently the scoring system is basic but with some work could provide the student with personal feedback. At the end of the case a formal evaluation of the student's performance could be provided, indicating where the student needs to improve and congratulating the student on good case management. If the case is terminated, the correct diagnosis and path leading to the diagnosis could be provided for the student if requested. In addition, the student could be provided with references to relevant medical literature.

A further consideration is to represent the time involved in managing the case by having the patient simulator keep track of time as the management of the case proceeds.

The time could be displayed to the student if requested. If actions performed on the patient are pending, time would be advanced through the patient simulator.

8.3. Future Considerations For the Implementation/Installation Phase

Future considerations that would require further work in the implementation/installation phase of the KADS methodology is the testing of the students. The sample tested within this study was comprised of students from Carleton University and from the University of Ottawa. It would be useful to test junior students and students from other universities to allow for greater external validity.

An additional consideration within the implementation/installation phase would be to create a task list, often used in usability studies, and a questionnaire related to the task list to provide more quantitative results from the testing sessions. As the system is a prototype, mainly qualitative feedback was wanted during the testing sessions to allow for frequent iterations of the prototype.

A final consideration would be to enlist the aid of more than one medical expert in eliciting the knowledge and evaluating the patient simulator.

The researcher strongly encourages the continuation of this study by other students as it is an exciting and worthwhile area of research. This study could serve as a platform for further studies in the medical education field and related fields and with the implementation of some or all of the above considerations, could provide numerous topics for further research.

2

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS
STANDARD REFERENCE MATERIAL 1010a
(ANSI and ISO TEST CHART No. 2)

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Glossary of Medical Terms

Appendix A Glossary of Medical Terms

Bacterial Intestinal Infection - An infection within the small or large intestines caused by bacteria. Examples of this infection are: cholera, staphylococcal food poisoning and gastroenteritis (inflammation of the membranes of the intestines and the stomach).

Bacterial Neurological Infection - An infection within the nervous system (the system of nerves and nerve cells consisting of the brain and spinal cord) caused by bacteria. Some examples of this infection are acute bacterial meningitis and recurrent meningitis.

Bacterial Culture - A colony or growth of bacteria of a given kind that has been made for a special purpose.

Cell Smear - Cells spread on a slide for microscopic examination or on the surface of a culture medium.

Clinical Medicine - Medicine dealing with the observation and treatment of patients. *

CSF Exam (Cerebral Spinal Fluid Exam) - Examination of the cerebral spinal fluid.

Diagnosis - The identification of a infection by means of a patient's symptoms. *

Fontanel - A membrane-covered spot on the growing skull of an infant or fetus. *

Intravenous Rehydration - The replacement of fluids in the body through a vein or veins.

Ketone - An organic compound with a carbonyl group attracted to two carbon atoms.

Neutrophil - A finely granular cell that is the chief phagocytic leukocyte (a cell engulfing foreign bodies) of the blood.

Oral Rehydration - The replacement of fluids in the body through the mouth.

Parasites - An animal or plant that lives on, with, or in another, from which it gets its food such as lice and tapeworms.

Prosthetics - Unnatural body parts such as artificial legs and a false tooth.

Viral Intestinal Infection - An infection within the small or large intestines caused by a virus. Examples of this type of infection are viral gastroenteritis or the intestinal flu.

Virus - Any of a group of infection-producing agents smaller than any known bacteria and dependent upon the living tissue of hosts for their reproduction and growth.

* Definitions obtained from the Dictionary of Canadian English, 1967

Description of Expert Consultations

Appendix B

Description of Expert Consultations

First Consultation

Date: Monday December 18th, 1992

Subject: Introductions

Details:

- 1) Discussion of research problem - development and testing of a patient simulator.
- 2) Determination of scope of thesis - knowledge base will represent at least two infections, to a maximum of three.
- 3) Discussion of student testing format - list of six third year undergraduate medical students will be provided by Dr. Rubin.
- 4) Discussion of expert availability.

Second Consultation

Date: Tuesday February 16th, 1993

Subject: Demonstration of Patient Simulator

Details:

- 1) Dr. Rubin is given a demonstration of the patient simulator with one case (viral intestinal infection). He provides feedback regarding the graphical user interface and the medical language. He feels that the structure of the patient simulator is good and recommends that testing could begin following the minor modifications as recommended.
- 2) Discussion also occurs as to what infection would be useful in addition to a viral intestinal infection. It was determined that a neurological infection has very similar symptoms to an intestinal infection yet requires a completely different diagnosis.

Third Consultation

Date: Tuesday March 30th, 1993

Subject: Bacterial Neurological Infection Model

Details:

- 1) Dr. Rubin is shown a model of a bacterial neurological infection as seen below. He makes corrections to the model and provides feedback. The following example is an example of the written model which was shown to Dr. Rubin. Once corrections were made to the model it was transformed into the diagrams of the sick infant as well as into the case management models.

Initial Representation Shown to Expert **Bacterial Infection of the Neurological System**

Symptoms

- irritation
- vomiting
- diarrhea

Patient History

- no change in diet
- no similar family symptoms
- normal bowel movement
- no previous treatment
- no prosthetics
- no chronic infections

General Exam

- pulse high
- behaviour abnormal
- fever of 38
- blood pressure high
- head size increased
- age (variable)
- loss of weight is 0%
- fontanel is tight
- mouth is dry
- skin is normal
- pupils are unequal

General Tests

- blood test
 - the number of red cells are normal
 - the number of white cells are increased (25000)
 - cell smear is normal
- urine test
 - the level of ketones is elevated
 - blood not in urine
 - sugar is absent
 - the level of proteins are increased

Interim Treatment

- antibiotics
- intravenous rehydration

Specific Tests

- C.s.f. exam
 - neutrophils increase
 - bands increase

- 2) Discussion also occurs as to what further infections would be useful to develop within the patient simulator and it is determined that a bacterial intestinal infection would have similar symptoms as the other two models and would add some diversity to the knowledge base.

Fourth Consultation

Date: Wednesday May 5th, 1993

Subject: Testing

Details:

- 1) Dr. Rubin is shown the comments and feedback from the first testing session. As some of the feedback from the students requires medical knowledge to determine if the suggestions are necessary and/or feasible.

Fifth Consultation

Date: Tuesday June 8th, 1993

Subject: Demonstration of bacterial neurological infection case in the patient simulator and discussion of the model of bacterial intestinal infection.

Details: This is an example of the written model which was shown to Dr. Rubin. Once corrections were made to the model it was transformed into the diagrams of the sick infant as well as into the case management models.

1)

Initial Representation Shown to Expert **Bacterial Infection of the Intestinal Tract**

Symptoms

- irritation
- vomiting
- diarrhea
- refusal to eat

Patient History

- no change in diet
- no similar family symptoms
- normal bowel movement
- no previous treatment
- no prosthetics

General Exam

- pulse high
- behaviour normal
- fever of 38
- blood pressure low
- head size normal
- age 13 months
- loss of weight is variable %
- fontanel is normal
- mouth is dry
- skin is normal

General Tests

- blood test
 - number of red cells are normal
 - number of white cells are normal
 - cell smear is normal
- urine test
 - level of ketones is elevated
 - blood absent in urine
 - sugar is absent
 - level of proteins are increased

Interim Treatment

If weight loss is <- 10% then oral rehydration

If weight loss is >10 % then hospitalization and intravenous rehydration

Specific Tests

- abdominal x-ray
 - negative
- stool test
 - blood is absent
 - bacterial culture is positive
 - pass is absent
 - parasites are absent
 - viral is negative

2) Dr. Rubin was shown a demonstration of the bacterial neurological infection case within the patient simulator.

Model of a Bacterial Neurological Infection

Appendix C

Model of a Bacterial Neurological Infection

i. Initial Representation

ii. Representation 1

iii. Representation 2

iv. Final Representation

Model of a Bacterial Intestinal Infection

Appendix D

Model of a Bacterial Intestinal Infection

i. Initial Representation

ii. Representation 1

iii. Representation 2

iv. Final Representation

**Case Management Models of a Bacterial Neurological Infection
and of a Bacterial Intestinal Infection**

Appendix E

Case Management Model of a Bacterial Neurological Infection

Appendix F

Case Management Model of a Bacterial Intestinal Infection

Case Management Model of a Terminated Bacterial Neurological Case

Appendix G **Case Management Model of a Terminated Bacterial Neurological Case**

Conditions for Termination

The following conditions are the circumstances under which a bacterial neurological case is terminated:

- infant is hospitalized;
- specialist is contacted prior to diagnosis;
- an unacceptable amount of time passes before one of the steps of case management is selected;
- the case management process is performed out of its intended order;
- the incorrect interim treatment is selected (correct interim treatment is intravenous rehydration and antibiotics);
- incorrect specific tests are requested (correct specific test is a C.s.f. exam);
- the incorrect diagnosis is made.

Case Management Model of a Terminated Bacterial Intestinal Case

Appendix H
Case Management Model of a Terminated Bacterial Intestinal Case

Conditions for Termination

The following conditions are the circumstances under which a bacterial neurological case is terminated:

- infant is hospitalized;
- specialist is contacted prior to diagnosis;
- an unacceptable amount of time passes before one of the steps of case management is selected;
- the case management process is performed out of its intended order;
- the incorrect interim treatment is selected (correct interim treatment for a weight loss of less than or equal to 10% is oral rehydration and for a weight loss of greater than 10% is intravenous rehydration and antibiotics);
- incorrect specific tests are requested (correct specific test is a stool test for weight loss less than or equal to 10% and a stool test and a blood test for weight loss greater than 10%);
- the incorrect diagnosis is made.

Load File

Appendix I Load File

The load file directs the patient simulator to a certain infection depending on what is selected by the user. Within the load file is the random component which allow for the randomized selection of an infection. In addition, the load file defines the symptoms which are the same for each disease for the current knowledge base.

```
%% patient: rules

:- dynamic <- /2.

us( sick_child ).
them( student ).
neutral( environment ).

selection_owner( student ).

% mbase_to_load( int_virus )
% mbase_to_load( int_bacteria )
% mbase_to_load( mgitis )

get_value1( irritability, V ) :-
    random_member( V, [neutral] ).

sick_child <- [ intestinal_system, neurological_system ].

intestinal_system <- [ bacterial_culture( int ), parasite( int ), virus( int ) ].

virus( int ) <- visible_symptoms(int, v1) + mbase_to_load( int_virus ).

visible_symptoms(int, v1) <- diarrhea(0) & vomiting(0) & 'refusal to eat'(0) &
    irritability(IR, 0) + get_value1(irritability, IR).

parasite( int ) <- visible_symptoms(int, p1).

visible_symptoms(int, p1) <- diarrhea & vomiting & refusal_to_eat &
    irritability(IR) + get_value1(irritability, IR).

bacterial_culture <- visible_symptoms( int, b1 ).
```

```
visible_symptoms( int, b1 ) <- diarrhea & vomiting & refusal_to_eat &
  irritability(IR) + get_value1(irritability, IR).
```

```
neurological_system <- [ bacteria( neu ), virus( neu )].
```

```
virus( neu ) <- visible_symptoms(neu, v1).
```

```
visible_symptoms(neu, v1) <- diarrhea(0) & vomiting(0) & 'refusal to eat'(0) &
  irritability(IR, 0) + get_value1(irritability, IR).
```

```
bacteria( neu ) <- visible_symptoms(neu, b1) + mbase_to_load( mgitis ) .
```

```
visible_symptoms(neu, b1) <- diarrhea(0) & vomiting(0) & 'refusal to eat'(0) &
  irritability(IR, 0) + get_value1(irritability, IR).
```

User Procedures File

Appendix J User Procedures File

The user procedures file defines the global maintained parameters, namely, the step and the score, throughout each run of the patient simulator.

```

%%% medicine: user_proc

% globally maintained parameters

read_param( Param, Value ) :-
  stored_param( Param, Value ),
  !.

write_param( Param, Value ) :-
  retract( stored_param( Param, _OldValue ) ),
  !,
  asserta( stored_param( Param, Value ) ).

% initial settings
:- dynamic stored_param / 2.

stored_param( score, 0 ) .
stored_param( step, 0 ) .
stored_param( modified, 0 ) .

% ----- handle TWO values

read_param2( Param, Value1, Value2 ) :-
  stored_param2( Param, Value1, Value2 ),
  !.

write_param2( Param, Value1, Value2 ) :-
  retract( stored_param2( Param, _OldValue1, _OldValue2 ) ),
  !,
  asserta( stored_param2( Param, Value1, Value2 ) ).

% initial settings
:- dynamic stored_param2 / 3.
stored_param2( score2, 0, 0 ) .

```

Customization File

Appendix K Customization File

The customization file provides the messages which are used in the patient simulator to communicate with the user. The following example is a copy of the customization file.

```
%%%
%%% medicine: customization
%%%

side_window( 'Environment', 'Evaluation' ).
side_window( 'User', 'Sick infant' ).
side_window( 'Other', 'Student' ).

custom_message(
    'Do you want to see Goal Representation', english,
    'Do you want to see the patient representation') :- !.

custom_message(
    'A modification rule fired. The new rule is', english,
    'Determining patient status ... ') :- !.

custom_message(
    'generate position stage', english,
    'Determining patient status ... ') :- !.

custom_message(
    'This is the end of negotiation', english,
    'This is the end of this simulation') :- !.

custom_message(
    'Nothing was preset in set option.', english,
    '') :- !.

custom_message(
    'The next round of negotiations has started.', english,
    '') :- !.

custom_message(
    'Intermediate phase', english,
    '') :- !.
```

```

custom_message(
    'Are you satisfied with generated position ', english,
    'Have you analyzed the current situation?'
) :- !.

custom_message(
    'Are you willing to change your goal tree ', english,
    'Select <yes> to see the results of your actions?'
) :- !.

custom_message(
    'End of Negotiation', english,
    'This is the end of this simulation'
) :- !.

custom_message(
    'These are the facts which make up our position.', english,
    'These facts are now known.'
) :- !.

custom_message(
    'A modification rule fired. The new rule is', english,
    'Restructuring.'
) :- !.

custom_message(
    'A modification rule fired.', english,
    'Restructuring.'
) :- !.

custom_message(
    'Inspect all current facts before continuing ? ', english,
    'Inspect metafacts before continuing?'
) :- !.

custom_message(
    'Forward chaining... have patience', english,
    'Processing your responses ... have patience'
) :- !.

custom_message(
    'NEGOPLAN : generic', english,
    '--generic message--'
) :- !.

custom_message(
    'Do you want to see Goal Representation', english,
    '--representation message--'
) :- !.

custom_message(
    'Forward chaining... have patience', english,
    '--forward chaining message--'
) :- !.

```

```

custom_message(
    'A modification rule fired. The new rule is', english,
    '--rule fired message--') :- !.

custom_message(
    'generate position stage', english,
    '--position message--') :- !.

custom_message(
    'This is the end of negotiation', english,
    '--end message--') :- !.

custom_message(
    'Nothing was preset in set option.', english,
    '--no preset message--') :- !.

custom_message(
    'The next round of negotiations has started.', english,
    '--next round message--') :- !.

custom_message(
    'Intermediate phase', english,
    '--intermediate message--') :- !.

custom_message(
    'Are you satisfied with generated position ', english,
    '--satisfied message--
') :- !.          % CR required in this message

custom_message(
    'Are you willing to change your goal tree ', english,
    '--change tree message--') :- !.

custom_message(
    'NEGOPLAN : set facts option ', english,
    '--set facts message--') :- !.

custom_message(
    'End of negoplan ', english,
    '--end message--') :- !.

custom_message(
    'End of Negotiation', english,
    '--end message--') :- !.

```



```

custom_message(
    'Results are displayed.', english,
    '--display message--') :- !.

custom_message(
    'These are the facts which make up our position.', english,
    '--facts message--') :- !.

custom_message(
    'Do you want to set preferences for any?', english,
    '--preferences message--') :- !.

custom_message(
    'Inspect all current facts before continuing ? ', english,
    '--inspect message--') :- !.

custom_message(
    'A modification rule fired. The new rule is', english,
    '--rule fired message--') :- !.

custom_message(
    'A modification rule fired.', english,
    '--rule fired message--') :- !.

***** end of patterns *****/

```

Knowledge Base For A Viral Intestinal Infection

Appendix L Knowledge Base for A Viral Intestinal Infection

```

%% medic: rebase.ext.intestinal
%% with scoring system

% ----- Initial conditions
step(0) ::= true .

% ----- Selection 1
sick_infant : diarrhea(0) ::= true & step(0) ::= true
==>
select ( 'general exam'(1), 'patient history'(1), 'contact specialist'(1),
        hospitalization(1) ) &
        step(1) ::= true & step(0) ::= false .

% ----- Modifications 1

%----- only general exam selected
step(1) ::= true &
    student : 'general exam'(1) ::= true &
    student : 'patient history'(1) ::= false &
    { write_param( modified, 1 ) }
==>
modify ( virus( int ) <-& general_exam,
        general_exam <- pulse( high, 1 ) & behaviour( normal, 1 ) & fever( 38, 1 ) &
        'blood pressure'( low, 1 ) & 'head size'( normal, 1 ) &
        age( '13 months', 1 ) & 'loss of weight'( '8 per cent', 1 ) &
        fontanel( ok, 1 ) & 'dry mouth'(1) & skin( normal, 1 ) ) .

% ----- patient history selected, exam - not
step(1) ::= true &
    student : 'general exam'(1) ::= false &
    student : 'patient history'(1) ::= true &
    { write_param( modified, 1 ) }
==>
modify ( virus( int ) <-& patient_history,
        patient_history <- diet( 'no change' ) & family( 'no similar symptoms' ) &
        'bowel movement'( normal ) & 'no previous treatment' ) .

% ----- patient history and exam selected
step(1) ::= true &
    student : 'general exam'(1) ::= true &
    student : 'patient history'(1) ::= true &
    { write_param( modified, 1 ) }

```

```

==>
modify ( virus( int ) <-& general_exam & patient_history,
        general_exam <- pulse( high, 1 ) & behaviour( normal, 1 ) & fever( 38, 1 ) &
        'blood pressure'( low, 1 ) & 'head size'( normal, 1 ) &
        age( '13 months', 1 ) & 'loss of weight'( 8, 'per cent', 1 ) &
        fontanel( ok, 1 ) & 'dry mouth'( 1 ) & skin( normal, 1 ),
        patient_history <- diet( 'no change' ) & family( 'no similar symptoms' ) &
        'bowel movement'( normal ) & 'no previous treatment' ) .

% ----- Selections 2

% ----- only history was requested
{ read_param( modified, 1 ) } &
  student : 'patient history'( 1 ) ::= true &
  student : 'general exam'( 1 ) ::= false
==>
select ( 'general tests'( 2 ), 'general exam'( 2 ), 'contact specialist'( 2 ),
        hospitalization( ^ ) ) &
  step( 1 ) ::= false & step( 2 ) ::= true .

% ----- only general exam was selected
{ read_param( modified, 1 ) } &
  student : 'general exam'( 1 ) ::= true &
  student : 'patient history'( 1 ) ::= false
==>
select ( 'general tests'( 2 ), 'contact specialist'( 2 ), 'patient history'( 2 ),
        'interim treatment'( 2 ), hospitalization( 2 ) ) &
  step( 1 ) ::= false & step( 2 ) ::= true .

% ----- both general exam and patient history selected
{ read_param( modified, 1 ) } &
  student : 'general exam'( 1 ) ::= true &
  student : 'patient history'( 1 ) ::= true
==>
select ( 'general tests'( 2 ), 'contact specialist'( 2 ),
        'interim treatment'( 2 ), hospitalization( 2 ) ) &
  step( 1 ) ::= false & step( 2 ) ::= true .

% ----- Modifications 2

% ----- only general exam requested (history - earlier)
step( 2 ) ::= true &
  student : 'general exam'( 2 ) ::= true &
  student : 'general tests'( 2 ) ::= false &
  { write_param( modified, 2 ) }

```

```

==>
modify ( virus( int ) <-& general_exam,
        general_exam <- pulse( high, 2 ) & behaviour( normal, 2 ) & fever( 38, 2 ) &
        'blood pressure'( low, 2 ) & 'head size'( normal, 2 ) &
        age( '13 months', 2 ) & 'loss of weight'( '8 per cent', 2 ) &
        fontanel( ok, 2 ) & 'dry mouth'(2) & skin( normal, 2 ) ) .

% ----- patient history selected, tests - not (exam - earlier)
step(2) ::= true &
    student : 'general tests'(2) ::= false &
    student : 'patient history'(2) ::= true &
    { write_param( modified, 2 ) }

==>
modify ( virus( int ) <-& patient_history,
        patient_history <- diet( 'no change' ) & family( 'no similar symptoms' ) &
        'bowel movement'( normal ) & 'no previous treatment' ) .

% ----- history and tests requested (exam - earlier)
step(2) ::= true &
    student : 'patient history'(2) ::= true &
    student : 'general tests'(2) ::= true &
    { write_param( modified, 2 ) }

==>
modify ( virus( int ) <-& patient_history & 'general tests'( pending, 2 ),
        patient_history <- diet( 'no change' ) & family( 'no similar symptoms' ) &
        'bowel movement'( normal ) & 'no previous treatment' ) .

% ----- general exam and tests requested (history - earlier)
step(2) ::= true &
    student : 'general exam'(2) ::= true &
    student : 'general tests'(2) ::= true &
    { write_param( modified, 2 ) }

==>
modify ( virus( int ) <-& general_exam & 'general tests'( pending, 2 ),
        general_exam <- pulse( high, 2 ) & behaviour( normal, 2 ) & fever( 38, 2 ) &
        'blood pressure'( low, 2 ) & 'head size'( normal, 2 ) &
        age( '13 months', 2 ) & 'loss of weight'( '8 per cent', 2 ) &
        fontanel( ok, 2 ) & 'dry mouth'(2) & skin( normal, 2 ) ) .

% ----- tests requested (general exam and history done)
% ----- interim treatment requested, or not
step(2) ::= true &
    student : 'general exam'(1) ::= true &
    student : 'patient history'(1) ::= true &
    student : 'general tests'(2) ::= true &
    { write_param( modified, 2 ) }

```

```

==>
modify ( virus( int ) <-& blood_test & urine_test,
        blood_test <- 'red cell'( normal, 2 ) & 'white cell'( normal, 2 ) &
        'cell smear'( normal, 2 ),
        urine_test <- ketones( elevated, 2 ) & 'blood in urine'( absent, 2 ) &
        sugar( absent, 2 ) & proteins( absent, 2 ) ) .

% ----- interim treatment requested, no general tests
% ----- (general exam and history done)
step(2) ::= true &
    student : 'interim treatment'(2) ::= true &
    { \+ existing_metafact( student, 'general tests'(_), true ) } &
    { write_param( modified, 2 ) }

==>
modify ( virus( int ) <-& visible_symptoms(int, v1),
        visible_symptoms(int, v1) <- diarrhea(2) & vomiting(2) &
        'refusal to eat'(2) & irritability(neutral, 2) ) .

%----- Selections 3

%----- history, exam and general tests requested, no interim treatment
{ read_param( modified, 2 ) } &
    student : 'general tests'(2) ::= true &
    { existing_metafact( student, 'general exam'(_), true ) } &
    { existing_metafact( student, 'patient history'(_), true ) } &
    { \+ existing_metafact( student, 'interim treatment'(_), true ) }

==>
select ( 'specific tests'( stool, 3 ), 'specific tests'('csf exam', 3 ),
        'specific tests'( urine, 3 ), 'specific tests'( 'lumbar puncture', 3 ),
        hospitalization(3), 'interim treatment'(3) ) &
    step(2) ::= false & step(3) ::= true .

% ----- general exam, history - requested, no tests, no treatment
{ read_param( modified, 2 ) } &
    student : 'general tests'(2) ::= false &
    { existing_metafact( student, 'patient history'(_), true ) } &
    { existing_metafact( student, 'general exam'(_), true ) } &
    { \+ existing_metafact( student, 'interim treatment'(_), true ) }

==>
select ( 'general tests'(3), 'contact specialist'(3), 'interim treatment'(3),
        hospitalization(3) ) &
    step(2) ::= false & step(3) ::= true .

```

```

% ----- general tests and interim treatment requested (history, exam earlier)
{ read_param( modified, 2 ) } &
  student : 'general tests'(2) ::= true &
  student : 'interim treatment'(2) ::= true &
  { existing_metafact( student, 'general exam'(_), true ) } &
  { existing_metafact( student, 'patient history'(_), true ) }
==>
select ( 'specific tests'( stool, 3 ), 'specific tests'('csf exam', 3 ),
  'specific tests'( urine, 3 ), 'specific tests'( 'lumbar puncture', 3 ),
  hospitalization(3), 'rehydration oral'(3),
  'rehydration intravenous'(3), antibiotic(3), 'contact specialist'(3) ) &
  step(2) ::= false & step(3) ::= true .

% ----- interim treatment requested, general exam and history done
% ----- no general tests
{ read_param( modified, 2 ) } &
  student : 'interim treatment'(2) ::= true &
  { existing_metafact( student, 'general exam'(_), true ) } &
  { existing_metafact( student, 'patient history'(_), true ) } &
  { \+ existing_metafact( student, 'general tests'(_), true ) }
==>
select ( hospitalization(3), 'rehydration oral'(3), antibiotic(3),
  'rehydration intravenous'(3), 'general tests'(3) ) &
  step(2) ::= false & step(3) ::= true .

% -----Modifications 3

% ----- interim treatment and general tests requested
% ----- then tests' result should be pending?
% ----- (general exam and history done)
step(3) ::= true &
  student : 'interim treatment'( 3 ) ::= true &
  student : 'general tests'( 3 ) ::= true &
  { \+ existing_metafact( student, 'specific tests'( _ , _ ), true ) } &
  { write_param( modified, 3 ) }
==>
modify ( viru. , int ) <-& visible_symptoms(int, v1) & 'general tests'( pending, 3 ),
  visible_symptoms(int, v1) <- diarrhea(3) & vomiting(3) &
  'refusal to eat'(3) & irritability(neutral, 3) ).

```

```

% ----- only interim treatment requested
% ----- (general tests, general exam and history done)
step(3) ::= true &
  student : 'interim treatment'( 3 ) ::= true &
  student : 'general tests'( 2 ) ::= true &
  { \+ existing_metafact( sick_infant, 'general tests'( pending, 2 ), true ) } &
  { \+ existing_metafact( student, 'specific tests'( _, _ ), true ) } &
  { write_param( modified, 3 ) }
==>
modify ( virus( int ) <-& visible_symptoms(int, v1),
  visible_symptoms(int, v1) <- diarrhea(3) & vomiting(3) &
  'refusal to eat'(3) & irritability(neutral, 3) ).

% ----- only interim treatment requested
% ----- (general tests : pending, general exam and history done)
step(3) ::= true &
  sick_infant : 'general tests'( pending, 2 ) ::= true &
  student : 'interim treatment'( 3 ) ::= true &
  { \+ existing_metafact( student, 'specific tests'( _, _ ), true ) } &
  { write_param( modified, 3 ) }
==>
modify ( virus( int ) <-& visible_symptoms(int, v1) & blood_test & urine_test,
  visible_symptoms(int, v1) <- diarrhea(3) & vomiting(3) &
  'refusal to eat'(3) & irritability(neutral, 3),
  blood_test <- 'red cell'( normal, 3 ) & 'white cell'( normal, 3 ) &
  'cell smear'( normal, 3 ),
  urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
  sugar( absent, 3 ) & proteins( absent, 3 ) ).

% ----- interim treatment requested, no general tests
% ----- (general exam and history done)
step(3) ::= true &
  student : 'interim treatment'( 3 ) ::= true &
  { \+ existing_metafact( student, 'general tests'(_), true ) } &
  { write_param( modified, 3 ) }
==>
modify ( virus( int ) <-& visible_symptoms(int, v1),
  visible_symptoms(int, v1) <- diarrhea(3) & vomiting(3) &
  'refusal to eat'(3) & irritability(neutral, 3) ).

% ----- only general tests requested, treatment earlier
step(3) ::= true &
  student : 'general tests'( 3 ) ::= true &
  student : 'interim treatment'( 2 ) ::= true &
  { write_param( modified, 3 ) }

```



```

==>
modify ( virus( int ) <-& blood_test & urine_test,
        blood_test <- 'red cell'( normal, 3 ) & 'white cell'( normal, 3 ) &
        'cell smear'( normal, 3 ),
        urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
        sugar( absent, 3 ) & proteins( absent, 3 ) ).

% ----- only general tests requested, no treatment
step(3) ::= true &
  student : 'general tests'( 3 ) ::= true &
  { \+ existing_metafact( student, 'interim treatment'(_), true ) } &
  { write_param( modified, 3 ) }

==>
modify ( virus( int ) <-& blood_test & urine_test,
        blood_test <- 'red cell'( normal, 3 ) & 'white cell'( normal, 3 ) &
        'cell smear'( normal, 3 ),
        urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
        sugar( absent, 3 ) & proteins( absent, 3 ) ).

% ----- only specific tests requested (general tests earlier)
step(3) ::= true &
  sick_infant : 'general tests'( pending, 2 ) ::= true &
  student : 'specific tests'( stool, 3 ) ::= true &
  { write_param( modified, 3 ) }

==>
modify ( virus( int ) <-& blood_test & urine_test & 'specific tests'(pending, 3 ),
        blood_test <- 'red cell'( normal, 3 ) & 'white cell'( normal, 3 ) &
        'cell smear'( normal, 3 ),
        urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
        sugar( absent, 3 ) & proteins( absent, 3 ) ).

% ----- specific tests requested only, no rehydration oral
% ----- general tests earlier
step(3) ::= true &
  student : 'specific tests'( stool, 3 ) ::= true &
  student : 'rehydration oral'(3) ::= false &
  { existing_metafact( student, 'general tests'(_), true ) } &
  { write_param( modified, 3 ) }

==>
modify ( virus( int ) <-& specific_tests( stool ),
        specific_tests( stool ) <- blood( absent, 3 ) & 'bacterial culture'( absent, 3 ) &
        pass( absent, 3 ) & parasites( absent, 3 ) & viral( positive, 3 ) ).

```

```

% ----- specific tests and correct treatment
step(3) ::= true &
  student : 'specific tests'( stool, 3 ) ::= true &
  student : 'rehydration oral'(3) ::= true &
  { existing_metafact( student, 'general tests'(_), true ) } &
  { write_param( modified, 3 ) }
==>
modify ( virus( int ) <-& visible_symptoms(int, v1) & specific_tests( stool ),
  visible_symptoms(int, v1) <- not diarrhea(3) & not vomiting(3) &
  irritability(neutral, 3 ),
  specific_tests( stool ) <- blood( absent,3 ) & 'bacterial culture'( absent, 3 ) &
  pass( absent, 3 ) & parasites( absent, 3 ) & viral( positive, 3 ) ) .

% ----- only specific tests, no treatment
step(3) ::= true &
  student : 'specific tests'( stool, 3 ) ::= true &
  { existing_metafact( student, 'general tests'(_), true ) } &
  { \+ existing_metafact( sick_infant, 'general tests'( pending, 2 ), true ) } &
  { \+ existing_metafact( student, 'interim treatment'(_), true ) } &
  { write_param( modified, 3 ) }
==>
modify ( virus( int ) <-& visible_symptoms(int, v1) & specific_tests( stool ),
  visible_symptoms(int, v1) <- diarrhea(3) & vomiting(3) &
  irritability(high, 3 ),
  specific_tests( stool ) <- blood( absent,3 ) & 'bacterial culture'( absent, 3 ) &
  pass( absent, 3 ) & parasites( absent, 3 ) & viral( positive, 3 ) ) .

% ----- only specific tests, no treatment
% ----- general tests(pending)
step(3) ::= true &
  student : 'specific tests'( stool, 3 ) ::= true &
  sick_infant : 'general tests'( pending, 2 ) ::= true &
  { \+ existing_metafact( student, 'interim treatment'(_), true ) } &
  { write_param( modified, 3 ) }

```

```

==>
modify ( virus( int ) <-& visible_symptoms(int, v1) & blood_test & urine_test
      & specific_tests( stool ),
      visible_symptoms(int, v1) <- diarrhea(3) & vomiting(3) &
      irritability(high, 3),
      blood_test <- 'red cell'( normal, 3 ) & 'white cell'( normal, 3 ) &
      'cell smear'( normal, 3 ),
      urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
      sugar( absent, 3 ) & proteins( absent, 3 ),
      specific_tests( stool ) <- blood( absent,3 ) & 'bacterial culture'( absent, 3 ) &
      pass( absent, 3 ) & parasites( absent, 3 ) & viral( positive, 3 ) ) .

```

```

%----- Selections 4

```

```

{ read_param( modified, 3 ) } &
  sick_infant : viral( positive, 3 ) ::= true &
  student : 'interim treatment'(3) ::= true

```

```

==>
select ( 'virus of intestinal tract'(4), 'parasite of intestinal tract'(4),
      'virus of neurological tract', 'rehydration oral'(4), antibiotic(4),
      'rehydration intravenous'(4), hospitalization(4) ) &
      step(3) ::= false & step(4) ::= true .

```

```

% general tests requested, no interim treatment

```

```

{ read_param( modified, 3 ) } &
  student : 'general tests'(3) ::= true &
    { existing_metafact( student, 'patient history'(), true ) } &
    { existing_metafact( student, 'general exam'(), true ) } &
    { \+ existing_metafact( student, 'interim treatment'(), true ) }

```

```

==>
select ( 'interim treatment'(4), 'contact specialist'(4), hospitalization(4),
      'specific tests'( stool, 4 ), 'specific tests'( 'csf exam', 4 ),
      'specific tests'( urine, 4 ), 'specific tests'( 'lumbar puncture', 4 ) ) &
      step(3) ::= false & step(4) ::= true .

```

```

% general tests requested (interim treatment earlier)

```

```

{ read_param( modified, 3 ) } &
  student : 'general tests'(3) ::= true &
  student : 'interim treatment'(2) ::= true

```

```

==>
select ( 'specific tests'( stool, 4 ), 'specific tests'( 'csf exam', 4 ),
      'specific tests'( urine, 4 ), 'specific tests'( 'lumbar puncture', 4 ),
      hospitalization(4), 'rehydration oral'(4), antibiotic(4),
      'rehydration intravenous'(4) ) &
      step(3) ::= false & step(4) ::= true

```

```

% interim treatment requested, no specific tests
{ read_param( modified, 3 ) } &
  student : 'interim treatment'(3) ::= true &
  student : 'general tests'(T) ::= true &
    { T < 4 } &
    { \+ existing_metafact( student, 'specific tests'( stool, _ ), true ) }
==>
select ( 'specific tests'( stool, 4 ), 'specific tests'( 'csf exam', 4 ),
  'specific tests'( urine, 4 ), 'specific tests'( 'lumbar puncture', 4 ),
  'rehydration oral'(4), antibiotic(4), 'rehydration intravenous'(4) ) &
  step(3) ::= false & step(4) ::= true .

% specific tests requested, no interim treatment
{ read_param( modified, 3 ) } &
  student : 'specific tests'( stool, 3 ) ::= true &
    { existing_metafact( student, 'patient history'(_), true ) } &
    { existing_metafact( student, 'general exam'(_), true ) } &
    { \+ existing_metafact( student, 'interim treatment'(_), true ) }
==>
select ( 'interim treatment'(4), 'contact specialist'(4), hospitalization(4),
  'specific tests'( 'csf exam', 4 ), 'specific tests'( urine, 4 ),
  'specific tests'( 'lumbar puncture', 4 ) ) &
  step(3) ::= false & step(4) ::= true .

% interim treatment requested, no general tests
{ read_param( modified, 3 ) } &
  student : 'interim treatment'(3) ::= true &
    { existing_metafact( student, 'patient history'(_), true ) } &
    { existing_metafact( student, 'general exam'(_), true ) } &
    { \+ existing_metafact( student, 'general tests'(_), true ) }
==>
select ( 'general tests'(4), 'contact specialist'(4), hospitalization(4),
  'rehydration oral'(4), antibiotic(4), 'rehydration intravenous'(4) ) &
  step(3) ::= false & step(4) ::= true .

% specific tests requested only, no rehydration oral
{ read_param( modified, 3 ) } &
  student : 'specific tests'( stool, 3 ) ::= true &
  student : 'rehydration oral'( 3 ) ::= false &
    { existing_metafact( student, 'patient history'(_), true ) } &
    { existing_metafact( student, 'general exam'(_), true ) }

```

```

==>
select ( 'rehydration oral'(4), antibiotic(4), 'rehydration intravenous'(4),
        'contact specialist'(4), hospitalization(4),
        'specific tests'('csf exam', 4 ), 'specific tests'( urine, 4 ),
        'specific tests'('lumbar puncture', 4 ) ) &
step(3) ::= false & step(4) ::= true .

% rehydration oral and 'specific tests'( stool) requested,
{ read_param( modified, 3 ) } &
  student : 'rehydration oral'(3) ::= true &
  student : 'specific tests'( stool, 3 ) ::= true &
    { existing_metafact( student, 'general tests'(_), true ) }
==>
select ('virus of intestinal tract'(4), 'parasite of intestinal tract'(4),
        'virus of neurological tract'(4) ) &
step(3) ::= false & step(4) ::= true .

% -----Modifications 4
% ----- general tests requested (history, exam, treatment done)
step(4) ::= true &
  student : 'general tests'(4) ::= true &
    { write_param( modified, 4 ) }
==>
modify ( virus( int ) <-& blood_test & urine_test,
        blood_test <- 'red cell'( normal, 4 ) & 'white cell'( normal, 4 ) &
          'cell smear'( normal, 4 ),
        urine_test <- ketones( elevated, 4 ) & 'blood in urine'( absent, 4 ) &
          sugar( absent, 4 ) & proteins( absent, 4 ) ) .

% ----- specific tests requested (interim treatment earlier)
step(4) ::= true &
  student : 'specific tests'( stool, 4 ) ::= true &
    { existing_metafact( student, 'interim treatment'(_), true ) } &
    { \+ existing_metafact( student, 'rehydration oral'(_), true ) } &
    { write_param( modified, 4 ) }
==>
modify ( virus( int ) <-& specific_tests( stool ),
        specific_tests( stool ) <- blood( absent, 4 ) & 'bacterial culture'( absent, 4 ) &
          pass( absent, 4 ) & parasites( absent, 4 ) & viral( positive, 4 ) ) .

% ----- interim treatment requested (specific tests earlier)
step(4) ::= true &
  student : 'specific tests'( stool, 3 ) ::= true &
    { \+ existing_metafact( sick_infant, 'specific tests'(pending, 3 ), true ) } &
  student : 'interim treatment'(4) ::= true &
    { write_param( modified, 4 ) }

```

```

==>
modify ( virus( int ) <-& visible_symptoms(int, v1),
        visible_symptoms(int, v1) <- diarrhea(4) & vomiting(4) &
        'refusal to eat'(4) & irritability(neutral, 4) ).

% ----- interim treatment requested (specific tests: pending earlier)
step(4) ::= true &
    sick_infant : 'specific tests'(pending, 3) ::= true &
    student : 'interim treatment'(4) ::= true &
    { write_param( modified, 4 ) }

==>
modify ( virus( int ) <-& visible_symptoms(int, v1) & specific_tests( stool ),
        visible_symptoms(int, v1) <- diarrhea(4) & vomiting(4) &
        'refusal to eat'(4) & irritability(neutral, 4),
        specific_tests( stool ) <- blood( absent, 4 ) & 'bacterial culture'( absent, 4 ) &
        pass( absent, 4 ) & parasites( absent, 4 ) & viral( positive, 4 ) ).

% ----- interim treatment and specific tests requested
step(4) ::= true &
    student : 'specific tests'( stool, 4 ) ::= true &
    student : 'interim treatment'(4) ::= true &
    { write_param( modified, 4 ) }

==>
modify ( virus( int ) <-& visible_symptoms(int, v1) & specific_tests( stool ),
        visible_symptoms(int, v1) <- diarrhea(4) & vomiting(4) &
        'refusal to eat'(4) & irritability(neutral, 4),
        specific_tests( stool ) <- blood( absent, 4 ) & 'bacterial culture'( absent, 4 ) &
        pass( absent, 4 ) & parasites( absent, 4 ) & viral( positive, 4 ) ).

% ----- specific tests requested, but no interim treatment
step(4) ::= true &
    student : 'specific tests'( stool, 4 ) ::= true &
    { \+ existing_metafact( student, 'interim treatment'(_), true ) } &
    { write_param( modified, 4 ) }

==>
modify ( virus( int ) <-& specific_tests( stool ),
        specific_tests( stool ) <- blood( absent, 4 ) & 'bacterial culture'( absent, 4 ) &
        pass( absent, 4 ) & parasites( absent, 4 ) & viral( positive, 4 ) ).

% ----- interim treatment requested, but no specific tests
step(4) ::= true &
    student : 'interim treatment'(4) ::= true &
    { \+ existing_metafact( student, 'specific tests'( stool, _ ), true ) } &
    { write_param( modified, 4 ) }

```

```

==>
modify ( virus( int ) <-& visible_symptoms(int, v1),
        visible_symptoms(int, v1) <- diarrhea(4) & vomiting(4) &
        'refusal to eat'(4) & irritability(neutral, 4) ).

% ----- only rehydration oral requested (specific tests earlier)
% (no pending tests)
step(4) ::= true &
    { \+ existing_metafact( sick_infant, 'specific tests'( pending, _ ), true ) } &
    student : 'specific tests'( stool, T ) ::= true &
    { T < 4 } &
    student : 'rehydration oral'(4) ::= true &
    { write_param( modified, 4 ) }

==>
modify ( virus( int ) <-& visible_symptoms(int, v1),
        visible_symptoms(int, v1) <- not diarrhea(4) & not vomiting(4) &
        irritability(neutral, 4) & not 'dry mouth'(4) ).

% ----- only rehydration oral requested (specific tests earlier)
step(4) ::= true &
    sick_infant : 'specific tests'( pending, 3 ) ::= true &
    student : 'rehydration oral'(4) ::= true &
    { write_param( modified, 4 ) }

==>
modify ( virus( int ) <-& visible_symptoms(int, v1) & specific_tests( stool ),
        visible_symptoms(int, v1) <- not diarrhea(4) & not vomiting(4) &
        irritability(neutral, 4) & not 'dry mouth'(4),
        specific_tests( stool ) <- blood( absent, 4 ) & 'bacterial culture'( absent, 4 ) &
        pass( absent, 4 ) & parasites( absent, 4 ) & viral( positive, 4 ) ).

% ----- oral rehydration requested and specific tests
% ----- general tests were pending at selection 3
step(4) ::= true &
    { existing_metafact( sick_infant, 'general tests'( pending, 3 ), true ) } &
    student : 'rehydration oral'(4) ::= true &
    student : 'specific tests'( stool, 4 ) ::= true &
    { write_param( modified, 4 ) }

```

```

==>
modify ( virus( int ) <-& visible_symptoms(int, v1) & blood_test & urine_test &
specific_tests( stool ),
    visible_symptoms(int, v1) <- not diarrhea(4) & not vomiting(4) &
    irritability(low, 4),
    blood_test <- 'red cell'( normal, 4 ) & 'white cell'( normal, 4 ) &
    'cell smear'( normal, 4 ),
    urine_test <- ketones( elevated, 4 ) & 'blood in urine'( absent, 4 ) &
    sugar( absent, 4 ) & proteins( absent, 4 ),
    specific_tests( stool ) <- blood( absent, 4 ) & bacterial_culture( absent, 4 ) &
    pass( absent ) & parasites( absent, 4 ) & viral( positive, 4 ) ) .

% ----- oral rehydration requested and specific tests
step(4) ::= true &
    student : 'rehydration oral'(4) ::= true &
    student : 'specific tests'( stool, 4 ) ::= true &
    { write_param( modified, 4 ) }

==>
modify ( virus( int ) <-& visible_symptoms(int, v1) & specific_tests( stool ),
    visible_symptoms(int, v1) <- not diarrhea(4) & not vomiting(4) &
    irritability(low, 4),
    specific_tests( stool ) <- blood( absent, 4 ) & bacterial_culture( absent, 4 ) &
    pass( absent ) & parasites( absent, 4 ) & viral( positive, 4 ) ) .

%----- Selections 5
%-----

% ----- general tests requested (history, exam, treatment done)
{ read_param( modified, 4 ) } &
    student : 'general tests'(4) ::= true

==>
select ( 'specific tests'( stool, 5 ), 'specific tests'('csf exam', 5 ),
    'specific tests'( urine, 5 ), 'specific tests'('lumbar puncture', 5 ),
    'rehydration oral'(5), antibiotic(5), 'rehydration intravenous'(5) ) &
    step(4) ::= false & 'specific tests'(5) ::= true .

% ----- interim treatment requested (specific tests earlier)
{ read_param( modified, 4 ) } &
    student : 'specific tests'( stool, 3 ) ::= true &
    { \+ existing_metafact( sick_infant, 'specific tests'(pending, 3 ), true ) } &
    student : 'interim treatment'(4) ::= true

```



```

==>
select ( hospitalization(5), 'contact specialist'(5), 'rehydration oral'(5),
        antibiotic(5), 'rehydration intravenous'(5) ) &
        step(4) ::= false & step(5) ::= true .

% ----- interim treatment requested, but no specific tests
{ read_param( modified, 4 ) } &
  student : 'interim treatment'(4) ::= true &
    { \+ existing_metafact( student, 'specific tests'( stool, _ ), true ) }
==>
select ( 'specific tests'( stool, 5 ), 'specific tests'( 'csf exam', 5 ),
        'specific tests'( urine, 5 ), 'specific tests'( 'lumbar puncture', 5 ),
        'rehydration oral'(5), antibiotic(5), 'rehydration intravenous'(5) ) &
        step(4) ::= false & step(5) ::= true .

% ----- specific tests requested (interim treatment earlier)
{ read_param( modified, 4 ) } &
  student : 'specific tests'( stool, 4 ) ::= true &
  student : 'interim treatment'(T) ::= true &
    { T < 4 } &
    { \+ existing_metafact( student, 'rehydration oral'(_), true ) }
==>
select ( hospitalization(5), 'contact specialist'(5), 'rehydration oral'(5),
        antibiotic(5), 'rehydration intravenous'(5) ) &
        step(4) ::= false & step(5) ::= true .

% ----- specific tests requested, but no interim treatment
{ read_param( modified, 4 ) } &
  student : 'specific tests'( stool, 4 ) ::= true &
    { \+ existing_metafact( student, 'interim treatment'(_), true ) }
==>
select ( 'interim treatment'(5), 'specific tests'( 'csf exam', 5 ),
        'specific tests'( urine, 5 ), 'specific tests'( 'lumbar puncture', 5 ),
        hospitalization(5), 'contact specialist'(5) ) &
        step(4) ::= false & step(5) ::= true .

% ----- interim treatment and specific tests requested
{ read_param( modified, 4 ) } &
  sick_infant : viral( positive, 4 ) ::= true &
  student : 'interim treatment'(4) ::= true

```

```

==>

```

```

select ( 'virus of intestinal tract'(5), 'parasite of intestinal tract'(5),
        'virus of neurological tract'(5), 'rehydration oral'(5), antibiotic(5),
        'rehydration intravenous'(5) ) &
        step(4) ::= false & step(5) ::= true .

% ----- correct treatment (specific tests earlier)
{ read_param( modified, 4 ) } &
  { \+ existing_metafact( sick_infant, 'specific tests'( pending, _ ), true ) } &
  student : 'specific tests'( stool, T ) ::= true &
  { T < 4 } &
  student : 'rehydration oral'(4) ::= true
==>
select ( 'virus of intestinal tract'(5), 'parasite of intestinal tract'(5),
        'virus of neurological tract'(5) ) &
        step(4) ::= false & step(5) ::= true .

% ----- specific tests and correct treatment
{ read_param( modified, 4 ) } &
  student : 'specific tests'(stool, 4) ::= true &
  student : 'rehydration oral'(4) ::= true
==>
select ( 'virus of intestinal tract'(5), 'parasite of intestinal tract'(5),
        'virus of neurological tract'(5) ) &
        step(4) ::= false & step(5) ::= true .

% -----Modifications 5

% ----- oral rehydration requested (specific tests done)
step(5) ::= true &
  student : 'rehydration oral'(5) ::= true &
  { write_param( modified, 5 ) }
==>
modify ( virus( int ) <-& visible_symptoms(int, v1),
        visible_symptoms(int, v1) <- not diarrhea(5) & not vomiting(5) &
        irritability(low, 5) ) .

%----- Selections 6
%-----
%
{ read_param( modified, 5 ) } &
  student : 'rehydration oral'(5) ::= true &
  { existing_metafact( student, 'specific tests'( stool, _ ), true ) }

==>

```

```

select ( 'virus of intestinal tract'(6), 'parasite of intestinal tract'(6),
        'virus of neurological tract'(6) ) &
step(5) ::= false & step(6) ::= true .

```

%-----TERMINATION RULES

```
% --- hospitalization requested, infant only sick
```

```
student : hospitalization( ) ::= true
```

```
==>
```

```
terminate ':
```

```
    Condition of the patient does not
    warrant hospitalization.' .
```

```
% --- contact specialist requested
```

```
student : 'contact specialist'( ) ::= true
```

```
==>
```

```
terminate ':
```

```
    No reason to contact a specialist'.
```

```
% --- no general exam requested after selection 2
```

```
step(2) ::= true &
```

```
    { \+ existing_metafact( student, 'general exam'( ), true ) }
```

```
==>
```

```
terminate ':
```

```
    You cannot proceed further.
```

```
    You must learn the management of the case.'.
```

```
% --- no history requested after selection 2
```

```
step(2) ::= true &
```

```
    { \+ existing_metafact( student, 'patient history'(T), true ) }
```

```
==>
```

```
terminate ':
```

```
    You cannot proceed further.
```

```
    You must learn the management of the case.'.
```

```
% --- no general exam but interim treatment requested
```

```
student : 'interim treatment'( ) ::= true &
```

```
    { \+ existing_metafact( student, 'general exam'( ), true ) }
```

```
==>
```

```
terminate ':
```

```
    No basis for interim treatment.
```

```
    General exam was not requested.' .
```

```

% --- patient history and interim treatment
% --- cannot be requested simultaneously
student : 'patient history'(2) ::= true &
student : 'interim treatment'(2) ::= true
==>
terminate ' :
    Without patient history,
    interim treatment cannot be requested.
    You must learn the management of the case.' .

% --- antibiotic requested
student : antibiotic( ) ::= true
==>
terminate ' :
    Incorrect treatment:
    antibiotic is not required.' .

% --- rehydration intravenous requested
student : 'rehydration intravenous'( ) ::= true
==>
terminate ' :
    Incorrect treatment:
    rehydration intravenous is not required.' .

% --- rehydration oral requested without general tests
student : 'rehydration oral'(T) ::= true &
    { \+ existing_metafact( student, 'general tests'( ), true ) }
==>
terminate ' :
    You cannot proceed further.
    You must learn the management of the case.' .

% --- the request of general tests must be prior to rehydration oral
student : 'rehydration oral'(T) ::= true &
student : 'general tests'(T) ::= true
==>
terminate ' :
    Rehydration oral cannot be requested
    without prior general tests.' .

```

```

% --- without specific tests
student : 'rehydration oral'(T) ::= true &
{ \+ existing_metafact( student, 'specific tests'( stool, _ ), true ) }
==>
terminate ':
    To make a correct diagnosis specific tests
    are required.' .

% --- Incorrect specific test requested
student : 'specific tests'( urine, _ ) ::= true
==>
terminate '
    Incorrect specific test were selected.
    Please consult the specialist.' .

% --- Incorrect specific test requested
student : 'specific tests'( 'lumbar puncture', _ ) ::= true
==>
terminate ':
    Incorrect specific test were selected.
    Please consult the specialist.' .

% --- Incorrect specific test requested
student : 'specific tests'( 'csf exam', _ ) ::= true
==>
terminate ':
    Incorrect specific test were selected.
    Please consult the specialist.' .

% --- too long for diagnosis
step(5) ::= true &
{ \+ existing_metafact( student, 'rehydration oral'(_), true ) }
==>
terminate ':
    The process is too long.
    You are advised to consult specialist' .

% --- Incorrect diagnosis
student : 'parasite of intestinal tract'(_) ::= true

==>

```

```

terminate ':
    Incorrect diagnosis.
    Please consult the specialist. ' .

% --- Incorrect diagnosis
student : 'virus of neurological tract'(_) ::= true

==>
terminate ':
    Incorrect diagnosis.
    Please consult the specialist. ' .

% --- Correct diagnosis, but incorrect treatment
student : 'virus of intestinal tract'(_) ::= true &
    { \+ existing_metafact( student, 'rehydration oral'(_), true ) }
==>
terminate ':
    The correct diagnosis: virus of the intestinal track.
    The interim treatment is incorrect. ' .

% --- Correct diagnosis and treatment
student : 'virus of intestinal tract'(_) ::= true &
student : 'rehydration oral'(_) ::= true
==>
terminate ':
    The correct diagnosis: virus of the intestinal track.
    The interim treatment: oral rehydration.
    Congratulations' .

% ----- SCORING SYSTEM
% ----- Evaluation 1
step(1) ::= true &
    student : 'general exam'(1) ::= true &
    student : 'patient history'(1) ::= false
==>
{ read_param( score, S ) } & score(S) ::= false & { S1 is S + 5 } &
    score( S1 ) ::= true & { write_param( score, S1 ) } .

step(1) ::= true &
    student : 'patient history'(1) ::= true &
    student : 'general exam'(1) ::= false

==>

```

```
{ read_param( score, S ) } & score(S) ::= false & { S1 is S + 5 } &
  score( S1 ) ::= true & { write_param( score, S1 ) } .
```

```
step(1) ::= true &
  student : 'general exam'(1) ::= true &
  student : 'patient history'(1) ::= true
```

```
==>
{ read_param( score, S ) } & score(S) ::= false & { S1 is S + 15 } &
  score( S1 ) ::= true & { write_param( score, S1 ) } .
```

```
% ----- Evaluation 2
```

```
step(2) ::= true &
  student : 'general tests'(2) ::= true &
  student : 'interim treatment'(2) ::= true
```

```
==>
{ read_param( score, S ) } & score(S) ::= false & { S2 is S + 15 } &
  score( S2 ) ::= true & { write_param( score, S2 ) } .
```

```
step(2) ::= true &
  student : 'general tests'(2) ::= true &
  student : 'interim treatment'(2) ::= false
```

```
==>
{ read_param( score, S ) } & score(S) ::= false & { S2 is S + 5 } &
  score( S2 ) ::= true & { write_param( score, S2 ) } .
```

```
step(2) ::= true &
  student : 'general tests'(2) ::= false &
  student : 'interim treatment'(2) ::= true
```

```
==>
{ read_param( score, S ) } & score(S) ::= false & { S2 is S + 5 } &
  score( S2 ) ::= true & { write_param( score, S2 ) } .
```

```
step(2) ::= true &
  student : 'general tests'(2) ::= true &
  student : 'patient history'(2) ::= true
```

```
==>
{ read_param( score, S ) } & score(S) ::= false & { S2 is S + 15 } &
  score( S2 ) ::= true & { write_param( score, S2 ) } .
```

```
step(2) ::= true &
  { \+ existing_metafact( student, 'general tests'(_), true ) } &
  student : 'patient history'(2) ::= true
```

```
==>
```

```

{ read_param( score, S ) } & score(S) ::= false & { S2 is S + 5 } &
  score( S2 ) ::= true & { write_param( score, S2 ) } .

step(2) ::= true &
  student : 'general tests'(2) ::= true &
  student : 'general exam'(2) ::= true

==>
{ read_param( score, S ) } & score(S) ::= false & { S2 is S + 15 } &
  score( S2 ) ::= true & { write_param( score, S2 ) } .

step(2) ::= true &
  { \+ existing_metafact( student, 'general tests'(_), true ) } &
  student : 'general exam'(2) ::= true
==>
{ read_param( score, S ) } & score(S) ::= false & { S2 is S + 5 } &
  score( S2 ) ::= true & { write_param( score, S2 ) } .

% ----- Evaluation 3
step(3) ::= true &
  student : 'specific tests'( stool, 3 ) ::= true &
  student : 'rehydration oral'(3) ::= true
==>
{ read_param( score, S ) } & score(S) ::= false & { S3 is S + 15 } &
  score( S3 ) ::= true & { write_param( score, S3 ) } .

step(3) ::= true &
  student : 'specific tests'( stool, 3 ) ::= true &
  student : 'interim treatment'(3) ::= true
==>
{ read_param( score, S ) } & score(S) ::= false & { S3 is S + 15 } &
  score( S3 ) ::= true & { write_param( score, S3 ) } .

step(3) ::= true &
  student : 'specific tests'( stool, 3 ) ::= true &
  student : 'rehydration oral'(3) ::= false
==>
{ read_param( score, S ) } & score(S) ::= false & { S3 is S + 5 } &
  score( S3 ) ::= true & { write_param( score, S3 ) } .

step(3) ::= true &
  student : 'specific tests'( stool, 3 ) ::= true &
  { \+ existing_metafact( student, 'interim treatment'(_), true &

==>

```



```

{ read_param( score, S ) } & score(S) ::= false & { S3 is S + 5 } &
  score( S3 ) ::= true & { write_param( score, S3 ) } .

step(3) ::= true &
  student : 'general tests'(3) ::= true &
  student : 'interim treatment'(3) ::= true

==>
{ read_param( score, S ) } & score(S) ::= false & { S3 is S + 15 } &
  score( S3 ) ::= true & { write_param( score, S3 ) } .

step(3) ::= true &
  student : 'interim treatment'(3) ::= true &
  student : 'specific tests'( stool, 3 ) ::= false

==>
{ read_param( score, S ) } & score(S) ::= false & { S3 is S + 5 } &
  score( S3 ) ::= true & { write_param( score, S3 ) } .

step(3) ::= true &
  student : 'interim treatment'(3) ::= true &
  { \+ existing_metafact( student, 'general tests'(_), true ) }

==>
{ read_param( score, S ) } & score(S) ::= false & { S3 is S + 5 } &
  score( S3 ) ::= true & { write_param( score, S3 ) } .

step(3) ::= true &
  student : 'general tests'(3) ::= true &
  student : 'rehydration oral'(3) ::= false

==>
{ read_param( score, S ) } & score(S) ::= false & { S3 is S + 5 } &
  score( S3 ) ::= true & { write_param( score, S3 ) } .

step(3) ::= true &
  student : 'general tests'(3) ::= true &
  { \+ existing_metafact( student, 'interim treatment'(_), true ) }

==>
{ read_param( score, S ) } & score(S) ::= false & { S3 is S + 5 } &
  score( S3 ) ::= true & { write_param( score, S3 ) } .

% ----- Evaluation 4
step(4) ::= true &
  student : 'virus of intestinal tract'(4) ::= true

```

```

==>

```

```
{ read_param( score, S ) } & score(S) ::= false & { S4 is S + 5 } &
  score( S4 ) ::= true & { write_param( score, S4 ) } &
done('total score is out of 50') ::= true.
```

```
step(4) ::= true &
  { existing_metafact( student, 'specific tests'( stool, T ), true ) } &
  { T < 4 } &
  student : 'rehydration oral'(4) ::= true
```

```
==>
{ read_param( score, S ) } & score(S) ::= false & { S4 is S + 5 } &
  score( S4 ) ::= true & { write_param( score, S4 ) } .
```

```
step(4) ::= true &
  student : 'specific tests'( stool, 4 ) ::= true &
  student : 'rehydration oral'(4) ::= true
```

```
==>
{ read_param( score, S ) } & score(S) ::= false & { S4 is S + 15 } &
  score( S4 ) ::= true & { write_param( score, S4 ) } .
```

```
step(4) ::= true &
  student : 'specific tests'( stool, 3 ) ::= true &
  student : 'interim treatment'(4) ::= true
```

```
==>
{ read_param( score, S ) } & score(S) ::= false & { S4 is S + 5 } &
  score( S4 ) ::= true & { write_param( score, S4 ) } .
```

```
step(4) ::= true &
  student : 'interim treatment'(4) ::= true &
  { \+ existing_metafact( student, 'specific tests'( stool, _ ), true ) }
```

```
==>
{ read_param( score, S ) } & score(S) ::= false & { S4 is S + 5 } &
  score( S4 ) ::= true & { write_param( score, S4 ) } .
```

```
step(4) ::= true &
  student : 'specific tests'( stool, 4 ) ::= true &
  { existing_metafact( student, 'interim treatment'(T), true ) } &
  { T < 4 }
```

```
==>
{ read_param( score, S ) } & score(S) ::= false & { S4 is S + 5 } &
  score( S4 ) ::= true & { write_param( score, S4 ) } .
```

```
step(4) ::= true &
  student : 'specific tests'( stool, 4 ) ::= true &
  student : 'interim treatment'(4) ::= true
```

```
==>
```

```
{ read_param( score, S ) } & score(S) ::= false & { S4 is S + 15 } &
  score( S4 ) ::= true & { write_param( score, S4 ) } .
```

```
% ----- Evaluation 5
```

```
step(5) ::= true &
  student : 'virus of intestinal tract'(5) ::= true &
  student : 'rehydration oral'(4) ::= true
```

```
==>
```

```
{ read_param( score, S ) } & score(S) ::= false & { S5 is S + 5 } &
  score( S5 ) ::= true & { write_param( score, S5 ) } &
done('total score is out of 50') ::= true.
```

```
step(5) ::= true &
  student : 'rehydration oral'(5) ::= true &
  { \+ existing_metafact( student, 'virus of intestinal tract'(_), true ) }
```

```
==>
```

```
{ read_param( score, S ) } & score(S) ::= false & { S5 is S + 5 } &
  score( S5 ) ::= true & { write_param( score, S5 ) } .
```

```
step(5) ::= true &
  student : 'virus of intestinal tract'(5) ::= true &
  student : 'rehydration oral'(5) ::= true
```

```
==>
```

```
{ read_param( score, S ) } & score(S) ::= false & { S5 is S + 15 } &
  score( S5 ) ::= true & { write_param( score, S5 ) } &
done('total score is out of 50') ::= true.
```

```
step(5) ::= true &
  student : 'specific tests'( stool, 5 ) ::= true &
  student : 'rehydration oral'(5) ::= true
```

```
==>
```

```
{ read_param( score, S ) } & score(S) ::= false & { S5 is S + 10 } &
  score( S5 ) ::= true & { write_param( score, S5 ) } .
```

```
% ----- Evaluation 6
```

```
step(6) ::= true &
  student : 'virus of intestinal tract'(6) ::= true
```

```
==>
```

```
{ read_param( score, S ) } & score(S) ::= false & { S6 is S + 5 } &
  score( S6 ) ::= true & { write_param( score, S6 ) } &
done('total score is out of 50') ::= true.
```

Knowledge Base for A Bacterial Neurological Infection

Appendix M

Knowledge Base for A Bacterial Neurological Infection

```
%% medic: rebase.meningitis
%% without scoring system
```

```
% ----- Initial Conditions
```

```
step(0) ::= true .
score(0) ::= true .
```

```
% ----- Selection 1
```

```
sick_infant : diarrhea(0) ::= true & step(0) ::= true
```

```
==>
```

```
select ( 'general exam'(1), 'patient history'(1), 'contact specialist'(1),
        hospitalization(1) ) &
        step(1) ::= true & step(0) ::= false .
```

```
% ----- Modifications 1
```

```
%--- general exam selected, history - not
```

```
step(1) ::= true &
    student : 'general exam'(1) ::= true &
    student : 'patient history'(1) ::= false &
    { write_param( modified, 1 ) }
```

```
==>
```

```
modify ( bacteria( neu ) <- & general_exam,
        general_exam <- pulse( high, 1 ) & behaviour( abnormal, 1 ) & fever( 38, 1 ) &
        'blood pressure'( high, 1 ) & 'head size'( increased, 1 )
        & age( '13 months', 1 ) & 'loss of weight'( '0 per cent', 1 ) &
        fontanel( tight, 1 ) & 'dry mouth'(1) & skin( normal, 1 ) &
        pupils( equal, 1 ) ) .
```

```
% ----- patient history selected, exam - not
```

```
step(1) ::= true &
    student : 'general exam'(1) ::= false &
    student : 'patient history'(1) ::= true &
    { write_param( modified, 1 ) }
```

```

==>
modify ( bacteria( neu ) <-& patient_history,
        patient_history <- diet( 'no change', 1 ) & family('no similar symptoms', 1) &
        'bowel movement'( normal, 1 ) & 'no previous treatment'(1) &
        'no prosthetics'(1) & 'no chronic infections'(1) &
        'length of symptoms'( '5 hours', 1 ) ).

% ----- patient history and exam selected
step(1) ::= true &
    student : 'general exam'(1) ::= true &
    student : 'patient history'(1) ::= true &
    { write_param( modified, 1 ) }

==>
modify ( bacteria( neu ) <-& general_exam & patient_history,
        general_exam <- pulse( high, 1 ) & behaviour( abnormal, 1 ) & fever( 38, 1 ) &
        'blood pressure'( high, 1 ) & 'head size'( increased, 1 ) &
        age( '13 months', 1 ) & 'loss of weight'( '0 per cent', 1 ) &
        fontanel( tight, 1 ) & 'dry mouth'(1) & skin( normal, 1 ) &
        pupils( equal, 1 ) ,
        patient_history <- diet( 'no change', 1 ) & family('no similar symptoms', 1) &
        'bowel movement'( normal, 1 ) & 'no previous treatment'(1) &
        'no prosthetics'(1) & 'no chronic infections'(1) &
        'length of symptoms'( '5 hours', 1 ) ).

% ----- Selections 2
% ----- first metafact of sick_infant taken

% ----- select rule when only history was selected
{ read_param( modified, 1 ) } &
    student : 'patient history'(1) ::= true &
    student : 'general exam'(1) ::= false

==>
select ( 'general tests'(2), 'general exam'(2), 'contact specialist'(2),
        hospitalization(2) ) &
    step(1) ::= false & step(2) ::= true .

% ----- only general exam was selected
{ read_param( modified, 1 ) } &
    student : 'general exam'(1) ::= true &
    student : 'patient history'(1) ::= false

```

```

==>
select ( 'general tests'(2), 'contact specialist'(2), 'patient history'(2),
        'interim treatment'(2), hospitalization(2) ) &
        step(1) ::= false & step(2) ::= true .

% ----- both general exam and patient history selected
{ read_param( modified, 1 ) } &
  student : 'general exam'(1) ::= true &
  student : 'patient history'(1) ::= true
==>
select ( 'general tests'(2), 'contact specialist'(2), 'interim treatment'(2),
        hospitalization(2) ) &
        step(1) ::= false & step(2) ::= true .

% -----Modifications 2
% ----- only general exam requested, history - earlier
step(2) ::= true &
  student : 'general exam'(2) ::= true &
  student : 'general tests'(2) ::= false &
  { write_param( modified, 2 ) }
==>
modify ( bacteria( neu ) <-& general_exam,
        general_exam <- pulse(high, 2) & behaviour(abnormal, 2) & fever(38.4, 2) &
        'blood pressure'(high, 2) & 'head size'(increased, 2) &
        age('13 months', 2) & 'loss of weight'('0 per cent', 2) &
        fontanel( tight, 2 ) & 'dry mouth'(2) &
        skin( normal, 2 ) & pupils( equal, 2 ) ) .

% ----- general exam and tests requested (history - earlier)
step(2) ::= true &
  student : 'general exam'(2) ::= true &
  student : 'general tests'(2) ::= true &
  { write_param( modified, 2 ) }
==>
modify ( bacteria( neu ) <-& general_exam & 'general tests'( pending, 2 ),
        general_exam <- pulse(high, 2) & behaviour(abnormal, 2) & fever(38.4, 2) &
        'blood pressure'(high, 2) & 'head size'(increased, 2) &
        age('13 months', 2) & 'loss of weight'('0 per cent', 2) &
        fontanel( tight, 2 ) & 'dry mouth'(2) &
        skin( normal, 2 ) & pupils( equal, 2 ) ) .

```

```

% ----- only patient history selected, exam - earlier
step(2) ::= true &
  student : 'general tests'(2) ::= false &
  student : 'patient history'(2) ::= true &
  { write_param( modified, 2 ) }

==>
modify ( bacteria( neu ) <-& patient_history,
  patient_history <- diet( 'no change', 2 ) & family('no similar symptoms', 2) &
  'bowel movement'( normal, 2 ) & 'no previous treatment'(2) &
  'no prosthetics'(2) & 'no chronic infections'(2) &
  'length of symptoms'( '5 hours', 2 ) ).

% ----- history and tests requested (exam - earlier)
step(2) ::= true &
  student : 'patient history'(2) ::= true &
  student : 'general tests'(2) ::= true &
  { write_param( modified, 2 ) }

==>
modify ( bacteria( neu ) <-& patient_history & 'general tests'( pending, 2 ),
  patient_history <- diet( 'no change', 2 ) & family('no similar symptoms', 2) &
  'bowel movement'( normal, 2 ) & 'no previous treatment'(2) &
  'no prosthetics'(2) & 'no chronic infections'(2) &
  'length of symptoms'( '5 hours', 2 ) ).

% ----- interim treatment requested, no general tests
% ----- (general exam and history done)
step(2) ::= true &
  student : 'interim treatment'(2) ::= true &
  { \+ existing_metafact( student, 'general tests'(_), true ) } &
  { write_param( modified, 2 ) }

==>
modify ( bacteria( neu ) <-& visible_symptoms(neu, b1),
  visible_symptoms(neu, b1) <- diarrhea(2) & vomiting(2) &
  'refusal to eat'(2) & irritability(neutral, 2 ) ).

% ----- general tests requested, exam and history - earlier,
% ----- interim treatment requested, or not
step(2) ::= true &
  student : 'general exam'(1) ::= true &
  student : 'patient history'(1) ::= true &
  student : 'general tests'(2) ::= true &
  { write_param( modified, 2 ) }

```



```

==>
modify ( bacteria( neu ) <-& blood_test & urine_test,
        blood_test <- 'red cell'( normal, 2 ) & 'white cell'( 25000, 2 ) &
        'cell smear'( normal, 2 ),
        urine_test <- ketones( elevated, 2 ) & 'blood in urine'( absent, 2 ) &
        sugar( absent, 2 ) & proteins( increase, 2 ) ).

%----- Selections 3
%-----
%----- history, general exam requested, no general tests and treatment
{ read_param( modified, 2 ) } &
  { existing_metafact( student, 'patient history'(_), true ) } &
  { existing_metafact( student, 'general exam'(_), true ) } &
  student : 'general tests'(2) ::= false &
  { \+ existing_metafact( student, 'interim treatment'(_), true ) }

==>
select ( 'general tests'(3), 'contact specialist'(3), 'interim treatment'(3),
        hospitalization(3) ) &
        step(2) ::= false & step(3) ::= true .

% ----- treatment requested, no general tests
% ----- general exam and history earlier
{ read_param( modified, 2 ) } &
  student : 'general exam'(1) ::= true &
  student : 'patient history'(1) ::= true &
  student : 'interim treatment'(2) ::= true &
  { \+ existing_metafact( student, 'general tests'(_), true ) }

==>
select ( 'general tests'(3), 'contact specialist'(3), 'rehydration oral'(3),
        antibiotic(3), 'rehydration intravenous'(3), hospitalization(3) ) &
        step(2) ::= false & step(3) ::= true .

% ----- general tests requested, history and exam - earlier, no interim treatment
{ read_param( modified, 2 ) } &
  student : 'general tests'(2) ::= true &
  { existing_metafact( student, 'general exam'(_), true ) } &
  { existing_metafact( student, 'patient history'(_), true ) } &
  { \+ existing_metafact( student, 'interim treatment'(_), true ) }

==>
select ( 'specific test'( stool, 3 ), 'specific test'( 'csf exam', 3 ),
        'specific test'( urine, 3 ), hospitalization(3), 'interim treatment'(3) ) &
        step(2) ::= false & step(3) ::= true .

```

```

% ----- interim treatment and tests requested, history and exam - earlier
{ read_param( modified, 2 ) } &
  student : 'interim treatment'(2) ::= true &
  student : 'general tests'(2) ::= true &
  student : 'general exam'(1) ::= true &
  student : 'patient history'(1) ::= true
==>
select ( 'rehydration oral'(3), 'rehydration intravenous'(3), antibiotic(3),
  hospitalization(3), 'specific test'(stool, 3), 'specific test'(urine, 3),
  'specific test'(csf exam, 3), 'contact specialist'(3) ) &
  step(2) ::= false & step(3) ::= true .

% -----Modifications 3
%-----

% ----- only general tests requested, no treatment
step(3) ::= true &
  student : 'general tests'(3) ::= true &
  { \+ existing_metafact( student, 'interim treatment'(_), true ) } &
  { write_param( modified, 3 ) }
==>
modify ( bacteria( neu ) <-& blood_test & urine_test,
  blood_test <- 'red cell'( normal, 3 ) & 'white cell'( 25000, 3 ) &
  'cell smear'( normal, 3 ),
  urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
  sugar( absent, 3 ) & proteins( increase, 3 ) ) .

% ----- only general tests requested, treatment earlier
step(3) ::= true &
  student : 'general tests'(3) ::= true &
  student : 'interim treatment'(2) ::= true &
  { write_param( modified, 3 ) }
==>
modify ( bacteria( neu ) <-& blood_test & urine_test,
  blood_test <- 'red cell'( normal, 3 ) & 'white cell'( 25000, 3 ) &
  'cell smear'( normal, 3 ),
  urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
  sugar( absent, 3 ) & proteins( increase, 3 ) ) .

```

```

% ----- general tests and treatment requested
% ----- then tests' result should be pending
step(3) ::= true &
  student : 'general tests'(3) ::= true &
    student : 'interim treatment'(3) ::= true &
    { write_param( modified, 3 ) }
==>
modify ( bacteria( neu ) <-& visible_symptoms(neu, b1) & 'general tests'( pending, 3 ),
  visible_symptoms(neu, b1) <- diarrhea(3) & vomiting(3) &
    'refusal to eat'(3) & irritability(neutral, 3) ) .

% ----- treatment and specific test requested
% ----- general tests were pending
% ----- exam, history earlier
step(3) ::= true &
  sick_infant : 'general tests'(pending, 2) ::= true &
  student : 'specific test'( 'csf exam', 3 ) ::= true &
    student : 'interim treatment'(3) ::= true &
    { write_param( modified, 3 ) }
==>
modify ( bacteria( neu ) <-& blood_test & urine_test & 'specific test'(pending, 3 ),
  blood_test <- 'red cell'( normal, 3 ) & 'white cell'( 25000, 3 ) &
    'cell smear'( normal, 3 ),
  urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
    sugar( absent, 3 ) & proteins( increase, 3 ) ) .

% ----- treatment and specific test requested
% ----- NO pending on general tests
% ----- exam, history, general tests earlier
step(3) ::= true &
  { \+ existing_metafact( sick_infant, 'general tests'(pending, _), true ) } &
  student : 'specific test'( 'csf exam', 3 ) ::= true &
    student : 'interim treatment'(3) ::= true &
    { write_param( modified, 3 ) }

==>
modify ( bacteria( neu ) <-& visible_symptoms(neu, b1) & 'specific test'(pending, 3 ),
  visible_symptoms(neu, b1) <- diarrhea(3) & vomiting(3) &
    'refusal to eat'(3) & irritability(neutral, 3) ) .

```

```

% ----- only treatment requested
% ----- general tests were pending
% ----- no specific test
step(3) ::= true &
    student : 'interim treatment'(3) ::= true &
    sick_infant : 'general tests'(pending, 2) ::= true &
    { \+ existing_metafact( student, 'specific test'( 'csf exam', _ ), true ) } &
    { write_param( modified, 3 ) }
==>
modify ( bacteria( neu ) <-& blood_test & urine_test,
    blood_test <- 'red cell'( normal, 3 ) & 'white cell'( 25000, 3 ) &
    'cell smear'( normal, 3 ) ,
    urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
    sugar( absent, 3 ) & proteins( increase, 3 ) ) .

% ----- only treatment requested
% ----- no pending on general tests
% ----- no specific test
step(3) ::= true &
    student : 'interim treatment'(3) ::= true &
    student : 'general tests'(2) ::= true &
    { \+ existing_metafact( sick_infant, 'general tests'(pending, _), true ) } &
    { \+ existing_metafact( student, 'specific test'( 'csf exam', _ ), true ) } &
    { write_param( modified, 3 ) }
==>
modify ( bacteria( neu ) <-& visible_symptoms(neu, b1),
    visible_symptoms(neu, b1) <- diarrhea(3) & vomiting(3) &
    'refusal to eat'(3) & irritability(neutral, 3) ) .

% ----- only treatment requested, no general tests
step(3) ::= true &
    student : 'interim treatment'(3) ::= true &
    student : 'general tests'(3) ::= false &
    { existing_metafact( student, 'general exam'(_), true ) } &
    { existing_metafact( student, 'patient history'(_), true ) } &
    { write_param( modified, 3 ) }

==>
modify ( bacteria( neu ) <-& visible_symptoms(neu, b1),
    visible_symptoms(neu, b1) <- diarrhea(3) & vomiting(3) &
    'refusal to eat'(3) & irritability(neutral, 3) ) .

```

```

% ----- only specific test requested
% ----- general tests were pending
% ----- no treatment
step(3) ::= true &
  sick_infant : 'general tests'(pending, 2) ::= true &
    student : 'specific test'('csf exam', 3) ::= true &
      { \+ existing_metafact( student, 'interim treatment'(_), true ) } &
      { write_param( modified, 3 ) }
==>
modify ( bacteria( neu ) <-& blood_test & urine_test & specific_tests('csf exam'),
  blood_test <- 'red cell'( normal, 3 ) & 'white cell'( 25000, 3 ) &
    'cell smear'( normal, 3 ),
  urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
    sugar( absent, 3 ) & proteins( increase, 3 ),
  specific_tests('csf exam') <- neutrophils( increase, 3 ) & bands( increase, 3 ) ).

% ----- only specific test requested
% ----- treatment done
step(3) ::= true &
  student : 'interim treatment'(2) ::= true &
  student : 'general tests'(2) ::= true &
  student : 'specific test'('csf exam', 3) ::= true &
  student : 'rehydration intravenous'(3) ::= false &
  student : antibiotic(3) ::= false &
  { write_param( modified, 3 ) }
==>
modify ( bacteria( neu ) <-& specific_tests('csf exam'),
  specific_tests('csf exam') <- neutrophils( increase, 3 ) & bands( increase, 3 ) ).

% ----- only specific test requested
% ----- No pending on general tests
% ----- no treatment
step(3) ::= true &
  student : 'specific test'('csf exam', 3) ::= true &
  { \+ existing_metafact( sick_infant, 'general tests'(pending, _), true ) } &
  { \+ existing_metafact( student, 'interim treatment'(_), true ) } &
  { write_param( modified, 3 ) }

==>
modify ( bacteria( neu ) <-& specific_tests('csf exam'),
  specific_tests('csf exam') <- neutrophils( increase, 3 ) & bands( increase, 3 ) ).

```

```

% ----- specific test, IV reh & antibiotic
% ----- exam, history, general tests, interim treatment - earlier
step(3) ::= true &
  student : 'rehydration intravenous'(3) ::= true &
    student : antibiotic(3) ::= true &
    student : 'specific test'( 'csf exam', 3 ) ::= true &
    { existing_metafact( student, 'general tests'(_), true ) } &
    { existing_metafact( student, 'interim treatment'(_), true ) } &
    { write_param( modified, 3 ) }
==>
modify ( bacteria( neu ) <-& visible_symptoms(neu, b1) & specific_tests('csf exam'),
  visible_symptoms(neu, b1) <- not diarrhea(3) & not vomiting(3) &
  irritability(neutral, 3) & not 'dry mouth'(3),
  specific_tests('csf exam') <- neutrophils(increase, 3) & bands(increase, 3) ).

% ----- intravenous rehydration and antibiotic requested
% ----- specific test not
% ----- exam, history, general tests - earlier
step(3) ::= true &
  student : 'rehydration intravenous'(3) ::= true &
    student : antibiotic(3) ::= true &
    student : 'specific test'( 'csf exam', 3 ) ::= false &
    { existing_metafact( student, 'general tests'(_), true ) } &
    { existing_metafact( student, 'interim treatment'(_), true ) } &
    { write_param( modified, 3 ) }
==>
modify ( bacteria( neu ) <-& visible_symptoms(neu, b1),
  visible_symptoms(neu, b1) <- not diarrhea(3) & not vomiting(3) &
  irritability(neutral, 3) ).

% ----- intravenous rehydration and specific test requested
% ----- antibiotic not
% ----- exam, history, general tests, interim treatment - earlier
step(3) ::= true &
  student : 'rehydration intravenous'(3) ::= true &
  student : antibiotic(3) ::= false &
    student : 'specific test'( 'csf exam', 3 ) ::= true &
    { existing_metafact( student, 'general tests'(_), true ) } &
    { existing_metafact( student, 'interim treatment'(_), true ) } &
    { write_param( modified, 3 ) }

==>
modify ( bacteria( neu ) <-& visible_symptoms(neu, b1) & specific_tests('csf exam'),
  visible_symptoms(neu, b1) <- diarrhea(3) & not vomiting(3) &
  irritability(neutral, 3),
  specific_tests('csf exam') <- neutrophils(increase, 3) & bands(increase, 3) ).

```

```

% ----- antibiotic requested and specific test
% ----- intravenous rehydration not
% ----- exam, history, general tests, interim treatment - earlier
step(3) ::= true &
  student : antibiotic(3) ::= true &
  student : 'rehydration intravenous'(3) ::= false &
    student : 'specific test'( 'csf exam', 3 ) ::= true &
    { existing_metafact( student, 'general tests'(_), true ) } &
    { existing_metafact( student, 'interim treatment'(_), true ) } &
    { write_param( modified, 3 ) }
==>
modify ( bacteria( neu ) <-& visible_symptoms(neu, b1) & specific_tests('csf exam'),
  visible_symptoms(neu, b1) <- diarrhea(3) & not vomiting(3) &
  irritability(neutral, 3),
  specific_tests('csf exam') <- neutrophils(increase, 3) & bands(increase, 3) ).

%----- Selections 4
% ----- only general tests requested, no treatment
% ----- exam, history earlier
{ read_param( modified, 3 ) } &
  student : 'general tests'(3) ::= true &
  student : 'interim treatment'(3) ::= false &
  { existing_metafact( student, 'general exam'(_), true ) } &
  { existing_metafact( student, 'patient history'(_), true ) }
==>
select ( 'specific test'(urine, 4), 'specific test'(stool, 4), 'interim treatment'(4),
  'specific test'('csf exam', 4), hospitalization(4) ) &
  step(3) ::= false & step(4) ::= true.

% ----- only interim treatment requested, no general tests
% ----- exam, history earlier
{ read_param( modified, 3 ) } &
  student : 'general tests'(3) ::= false &
  student : 'interim treatment'(3) ::= true &
  { existing_metafact( student, 'general exam'(_), true ) } &
  { existing_metafact( student, 'patient history'(_), true ) }
==>
select ( 'general tests'(4), hospitalization(4), 'rehydration oral'(4),
  antibiotic(4), 'rehydration intravenous'(4) ) &
  step(3) ::= false & step(4) ::= true.

```

```

% ----- after selection 3, general tests, interim treatment have been requested
% ----- no specific test before
{ read_param( modified, 3 ) } &
  student : 'interim treatment'(3) ::= true &
  { existing_metafact( student, 'general tests'(T), true ) } &
  { T < 4 } &
  { \+ existing_metafact( student, 'specific test'( 'csf exam', _ ), true ) }
==>
select ( 'specific test'(urine, 4), 'specific test'(stool, 4),
  'specific test'( 'csf exam', 4), hospitalization(4), 'rehydration oral'(4),
  antibiotic(4), 'rehydration intravenous'(4) ) &
  step(3) ::= false & step(4) ::= true.

% ----- after selection 3, interim treatment, general tests, have been requested
% ----- no specific test before
{ read_param( modified, 3 ) } &
  student : 'general tests'(3) ::= true &
  { existing_metafact( student, 'interim treatment'(T), true ) } &
  { T < 4 } &
  { \+ existing_metafact( student, 'specific test'( 'csf exam', _ ), true ) }
==>
select ( 'specific test'(urine, 4), 'specific test'(stool, 4),
  'specific test'( 'csf exam', 4), hospitalization(4), 'rehydration oral'(4),
  antibiotic(4), 'rehydration intravenous'(4) ) &
  step(3) ::= false & step(4) ::= true.

% ----- specific test requested
% ----- no interim treatment before
{ read_param( modified, 3 ) } &
  student : 'specific test'( 'csf exam', 3 ) ::= true &
  student : 'rehydration intravenous'(3) ::= false &
  { \+ existing_metafact( student, 'interim treatment'(_), true ) } &
  { existing_metafact( student, 'general tests'(_), true ) }
==>
select ( 'specific test'(urine, 4), 'specific test'(stool, 4), hospitalization(4),
  'interim treatment'(4), 'contact specialist'(4) ) &
  step(3) ::= false & step(4) ::= true.

```



```

% ----- specific test requested
% ----- interim treatment done before
{ read_param( modified, 3 ) } &
  student : 'specific test'( 'csf exam', 3 ) ::= true &
  student : 'rehydration intravenous'(3) ::= false &
  student : antibiotic(3) ::= false &
    { existing_metafact( student, 'interim treatment'(2), true ) } &
    { existing_metafact( student, 'general tests'(2), true ) }
==>
select ( 'specific test'(urine, 4), 'specific test'(stool, 4),      hospitalization(4),
  'rehydration oral'(4), antibiotic(4), 'rehydration intravenous'(4) ) &
  step(3) ::= false & step(4) ::= true.

% ----- specific test and interim treatment requested
% ----- exam, history, general tests earlier
{ read_param( modified, 3 ) } &
  student : 'specific test'( 'csf exam', 3 ) ::= true &
  student : 'interim treatment'(3) ::= true &
    { existing_metafact( student, 'general exam'(_), true ) } &
    { existing_metafact( student, 'general tests'(_), true ) } &
    { existing_metafact( student, 'patient history'(_), true ) }
==>
select ( 'specific test'(urine, 4), 'specific test'(stool, 4),
  hospitalization(4), 'rehydration oral'(4), antibiotic(4),
  'rehydration intravenous'(4) ) &
  step(3) ::= false & step(4) ::= true.

% ----- intravenous rehydration and antibiotic requested
% ----- specific test not
{ read_param( modified, 3 ) } &
  student : 'rehydration intravenous'(3) ::= true &
  student : antibiotic(3) ::= true &
  student : 'specific test'( 'csf exam', 3 ) ::= false

==>
select ( 'specific test'(urine, 4), 'specific test'(stool, 4),
  'specific test'( 'csf exam', 4),      hospitalization(4), 'rehydration oral'(4) ) &
  step(3) ::= false & step(4) ::= true.

```

```

% ----- rehydration intravenous requested and specific test
% ----- exam, history, general tests, interim treatment - earlier
{ read_param(modified, 3) } &
  student : antibiotic(3) ::= false &
  student : 'rehydration intravenous'(3) ::= true &
  student : 'specific test'( 'csf exam', 3 ) ::= true
==>
select ( 'virus of intestinal tract'(4), 'parasite of intestinal tract'(4),
  'bacterial infection of neurological system'(4), 'contact neurologist'(4) ) &
  step(3) ::= false & step(4) ::= true.

% ----- antibiotic requested and specific test
% ----- exam, history, general tests, interim treatment - earlier
{ read_param(modified, 3) } &
  student : antibiotic(3) ::= true &
  student : 'rehydration intravenous'(3) ::= false &
  student : 'specific test'( 'csf exam', 3 ) ::= true
==>
select ( 'virus of intestinal tract'(4), 'parasite of intestinal tract'(4),
  'bacterial infection of neurological system'(4), 'contact neurologist'(4) ) &
  step(3) ::= false & step(4) ::= true.

% ----- all treatments correct and specific test
% ----- exam, history, general tests, interim treatment - earlier
{ read_param(modified, 3) } &
  student : antibiotic(3) ::= true &
  student : 'rehydration intravenous'(3) ::= true &
  student : 'specific test'( 'csf exam', 3 ) ::= true
==>
select ( 'virus of intestinal tract'(4), 'parasite of intestinal tract'(4),
  'bacterial infection of neurological system'(4), 'contact neurologist'(4) ) &
  step(3) ::= false & step(4) ::= true.

%-----Modifications 4

% ----- only general tests requested
% ----- interim treatment done
step(4) ::= true &
  student : 'interim treatment'(3) ::= true &
  student : 'general tests'(4) ::= true &
  { write_param( modified, 4 ) }

```

```

==>
modify ( bacteria( neu ) <-& blood_test & urine_test,
        blood_test <- 'red cell'( normal, 4 ) & 'white cell'( 25000, 4 ) &
        'cell smear'( normal, 4 ),
        urine_test <- ketones( elevated, 4 ) & 'blood in urine'( absent, 4 ) &
        sugar( absent, 4 ) & proteins( increase, 4 ) ) .

% ----- only interim treatment requested
% ----- specific test done before
% ----- exam, history, general tests - earlier
step(4) ::= true &
    student : 'interim treatment'(4) ::= true &
    student : 'specific test'('csf exam', 3) ::= true &
    { write_param( modified, 4 ) }

==>
modify ( bacteria( neu ) <-& visible_symptoms(neu, b1),
        visible_symptoms(neu, b1) <- diarrhea(4) & vomiting(4) &
        'refusal to eat'(4) & irritability(neutral, 4) ) .

% ----- only interim treatment requested, specific test not
% ----- exam, history, general tests - earlier
step(4) ::= true &
    student : 'interim treatment'(4) ::= true &
    { \+ existing_metafact( student, 'specific test'('csf exam', _), true ) } &
    { write_param( modified, 4 ) }

==>
modify ( bacteria( neu ) <-& visible_symptoms(neu, b1),
        visible_symptoms(neu, b1) <- diarrhea(4) & vomiting(4) &
        'refusal to eat'(4) & irritability(neutral, 4) ) .

% ----- interim treatment requested and specific test
% ----- exam, history, general tests - earlier
step(4) ::= true &
    student : 'interim treatment'(4) ::= true &
    student : 'specific test'('csf exam', 4) ::= true &
    { write_param( modified, 4 ) }

==>
modify ( bacteria( neu ) <-& visible_symptoms(neu, b1) & 'specific test'(pending, 4 ),
        visible_symptoms(neu, b1) <- diarrhea(4) & vomiting(4) &
        'refusal to eat'(4) & irritability(neutral, 4) ) .

```

```

% ----- only specific test requested
% ----- exam, history, general tests - earlier
% ----- interim treatment or not
step(4) ::= true &
    student : 'specific test'('csf exam', 4) ::= true &
    { \+ existing_metafact( student, antibiotic(_), true ) } &
    { \+ existing_metafact( student, 'rehydration intravenous'(_), true ) } &
    { write_param( modified, 4 ) }
==>
modify ( bacteria( neu ) <-& specific_tests('csf exam'),
        specific_tests('csf exam') <- neutrophils(increase, 4) & bands(increase, 4) ).

% ----- specific test, IV reh & antibiotic
% ----- exam, history, general tests, interim treatment - earlier
step(4) ::= true &
    student : 'rehydration intravenous'(4) ::= true &
    student : antibiotic(4) ::= true &
    student : 'specific test'('csf exam', 4) ::= true &
    { existing_metafact( student, 'general tests'(_), true ) } &
    { existing_metafact( student, 'interim treatment'(_), true ) } &
    { write_param( modified, 4 ) }
==>
modify ( bacteria( neu ) <-& visible_symptoms(neu, b1) & specific_tests('csf exam'),
        visible_symptoms(neu, b1) <- not diarrhea(4) & not vomiting(4) &
        irritability(neutral, 4) & not 'dry mouth'(4),
        specific_tests('csf exam') <- neutrophils(increase, 4) & bands(increase, 4) ).

% ----- intravenous rehydration and antibiotic requested
% ----- specific test not
% ----- exam, history, general tests - earlier
step(4) ::= true &
    student : 'rehydration intravenous'(4) ::= true &
    student : antibiotic(4) ::= true &
    { \+ existing_metafact( student, 'specific test'('csf exam', _), true ) } &
    student : 'general tests'(_ ) ::= true &
    { existing_metafact( student, 'interim treatment'(_), true ) } &
    { write_param( modified, 4 ) }
==>
modify ( bacteria( neu ) <-& visible_symptoms(neu, b1),
        visible_symptoms(neu, b1) <- not diarrhea(4) & not vomiting(4) &
        irritability(neutral, 4) ).

```

```

% ----- intravenous rehydration and specific test requested
% ----- antibiotic not
% ----- exam, history, general tests, interim treatment - earlier
step(4) ::= true &
  student : 'rehydration intravenous'(4) ::= true &
  student : antibiotic(4) ::= false &
    student : 'specific test'('csf exam', 4) ::= true &
    { existing_metafact( student, 'general tests'(_), true ) } &
    { existing_metafact( student, 'interim treatment'(_), true ) } &
    { write_param( modified, 4 ) }
==>
modify ( bacteria( neu ) <-& visible_symptoms(neu, b1) & specific_tests('csf exam'),
  visible_symptoms(neu, b1) <- diarrhea(4) & not vomiting(4) &
    irritability(neutral, 4),
  specific_tests('csf exam') <- neutrophils(increase, 4) & bands(increase, 4) ).

% ----- antibiotic requested and specific test
% ----- intravenous rehydration not
% ----- exam, history, general tests, interim treatment - earlier
step(4) ::= true &
  student : antibiotic(4) ::= true &
  student : 'rehydration intravenous'(4) ::= false &
    student : 'specific test'('csf exam', 4) ::= true &
    { existing_metafact( student, 'general tests'(_), true ) } &
    { existing_metafact( student, 'interim treatment'(_), true ) } &
    { write_param( modified, 4 ) }
==>
modify ( bacteria( neu ) <-& visible_symptoms(neu, b1) & specific_tests('csf exam'),
  visible_symptoms(neu, b1) <- diarrhea(4) & not vomiting(4) &
    irritability(neutral, 4),
  specific_tests('csf exam') <- neutrophils(increase, 4) & bands(increase, 4) ).

%----- only antibiotic requested
% ----- no pending on specific test before
step(4) ::= true &
  student : antibiotic(4) ::= true &
  student : 'rehydration intravenous'(4) ::= false &
    { existing_metafact( student, 'specific test'('csf exam', _), true ) } &
    { \+ existing_metafact( sick_infant, 'specific test'(pending, _), true ) } &
    { write_param( modified, 4 ) }

==>
modify ( bacteria( neu ) <-& visible_symptoms(neu, b1),
  visible_symptoms(neu, b1) <- diarrhea(4) & not vomiting(4) & irritability(neutral,
  4) & not 'dry mouth'(4) ).

```

```

%----- only rehydration intravenous requested
% ----- no pending on specific test before
step(4) ::= true &
  student : 'rehydration intravenous'(4) ::= true &
  student : antibiotic(4) ::= false &
  { existing_metafact( student, 'specific test'('csf exam', _), true )} &
  { \+ existing_metafact( sick_infant, 'specific test'(pending, _), true )} &
  { write_param( modified, 4) }

==>
modify ( bacteria( neu ) <-& visible_symptoms(neu, b1),
  visible_symptoms(neu, b1) <- not diarrhea(4) & not vomiting(4) &
  irritability(neutral, 4) ).

%----- antibiotic and rehydration intravenous requested
% ----- no pending on specific test before
step(4) ::= true &
  student : antibiotic(4) ::= true &
  student : 'rehydration intravenous'(4) ::= true &
  { existing_metafact( student, 'specific test'('csf exam', _), true )} &
  { \+ existing_metafact( sick_infant, 'specific test'(pending, _), true )} &
  { write_param( modified, 4) }

==>
modify ( bacteria( neu ) <-& visible_symptoms(neu, b1),
  visible_symptoms(neu, b1) <- not diarrhea(4) & not vomiting(4) &
  irritability(neutral, 4) & not 'dry mouth'(4) ).

%----- only antibiotic requested
% ----- specific test were pending before
step(4) ::= true &
  sick_infant : 'specific test'(pending, 3) ::= true &
  student : antibiotic(4) ::= true &
  student : 'rehydration intravenous'(4) ::= false &
  { write_param( modified, 4) }

==>
modify ( bacteria( neu ) <-& visible_symptoms(neu, b1) & specific_tests('csf exam'),
  visible_symptoms(neu, b1) <- diarrhea(4) & not vomiting(4) & irritability(neutral,
  4) & not 'dry mouth'(4),
  specific_tests('csf exam') <- neutrophils(increase, 4) & bands(increase, 4) ).

```

```

%----- only intravenous rehydration requested
% ----- specific test were pending before
step(4) ::= true &
    sick_infant : 'specific test'(pending, 3) ::= true &
    student : 'rehydration intravenous'(4) ::= true &
    student : antibiotic(4) ::= false &
    { write_param( modified, 4) }

==>
modify ( bacteria( neu ) <-& visible_symptoms(neu, b1) & specific_tests('csf exam'),
    visible_symptoms(neu, b1) <- not diarrhea(4) & vomiting(4) &
    irritability(neutral, 4) & not 'dry mouth'(4),
    specific_tests('csf exam') <- neutrophils(increase, 4) & bands(increase, 4) ).

% ----- antibiotic and intravenous rehydration requested
% ----- specific test were pending before
step(4) ::= true &
    sick_infant : 'specific test'(pending, 3) ::= true &
    student : 'rehydration intravenous'(4) ::= true &
    student : antibiotic(4) ::= true &
    { write_param( modified, 4) }

==>
modify ( bacteria( neu ) <-& visible_symptoms(neu, b1) & specific_tests('csf exam'),
    visible_symptoms(neu, b1) <- not diarrhea(4) & not vomiting(4) &
    irritability(neutral, 4) & not 'dry mouth'(4),
    specific_tests('csf exam') <- neutrophils(increase, 4) & bands(increase, 4) ).

% ----- only specific test requested
% ----- all correct treatments done
step(4) ::= true &
    student : 'rehydration intravenous'(3) ::= true &
    student : antibiotic(3) ::= true &
    student : 'specific test'('csf exam', 4) ::= true &
    { write_param( modified, 4) }

==>
modify ( bacteria( neu ) <-& visible_symptoms(neu, b1) & specific_tests('csf exam'),
    visible_symptoms(neu, b1) <- not diarrhea(4) & not vomiting(4) &
    irritability(neutral, 4) & not 'dry mouth'(4),
    specific_tests('csf exam') <- neutrophils(increase, 4) & bands(increase, 4) ).

%-----Selections 5
% ----- only interim treatment requested
% ----- no specific test before
{ read_param( modified, 4) } &
    student : 'interim treatment'(4) ::= true &
    student : 'specific test'('csf exam', 4) ::= false

```

```

==>
select ( 'specific test'(urine, 5), 'specific test'(stool, 5),
        'specific test'( 'csf exam', 5), hospitalization(5), 'rehydration oral'(5),
        antibiotic(5), 'rehydration intravenous'(5) ) &
        step(4) ::= false & step(5) ::= true.

% ----- only interim treatment requested
% ----- specific test done already
{ read_param( modified, 4 ) } &
  student : 'interim treatment'(4) ::= true &
  student : 'specific test'( 'csf exam', 3 ) ::= true
==>
select ( 'specific test'(urine, 5), 'specific test'(stool, 5),      hospitalization(5),
        'rehydration oral'(5), antibiotic(5), 'rehydration intravenous'(5) ) &
        step(4) ::= false & step(5) ::= true.

% ----- specific test and interim treatment requested
{ read_param( modified, 4 ) } &
  student : 'interim treatment'(4) ::= true &
  student : 'specific test'( 'csf exam', 4 ) ::= true
==>
select ( 'specific test'(urine, 5), 'specific test'(stool, 5), hospitalization(5),
        'rehydration oral'(5), antibiotic(5), 'rehydration intravenous'(5) ) &
        step(4) ::= false & step(5) ::= true.

% ----- only specific test requested, not interim treatment
{ read_param( modified, 4 ) } &
  student : 'interim treatment'(4) ::= false &
  student : 'specific test'( 'csf exam', 4 ) ::= true

==>
select ( 'specific test'(urine, 5), 'specific test'(stool, 5), hospitalization(5),
        'interim treatment'(5) ) &
        step(4) ::= false & step(5) ::= true.

% ----- only specific test requested
% ----- interim treatment done before
{ read_param( modified, 4 ) } &
  { existing_metafact( student, 'interim treatment'(T), true ) } &
  { T < 4 } &
  { \+ existing_metafact( student, antibiotic( ), true ) } &
  { \+ existing_metafact( student, 'rehydration intravenous'( ), true ) } &
  student : 'specific test'( 'csf exam', 4 ) ::= true

```



```

==>
select ( 'specific test'(urine, 5), 'specific test'(stool, 5), hospitalization(5),
        'rehydration oral'(5), antibiotic(5), 'rehydration intravenous'(5)) &
        step(4) ::= false & step(5) ::= true.

% ----- only general tests requested
% ----- interim treatment done before
{ read_param( modified, 4) } &
  { existing_metafact( student, 'interim treatment'(_), true ) } &
  student : 'general tests'( 4 ) ::= true

==>
select ( 'specific test'(urine, 5), 'specific test'(stool, 5),
        'specific test'('csf exam', 5), hospitalization(5), 'rehydration oral'(5),
        antibiotic(5), 'rehydration intravenous'(5) ) &
        step(4) ::= false & step(5) ::= true.

% ----- specific test done
% ----- all correct treatments done
{ read_param( modified, 4) } &
  { existing_metafact( student, antibiotic(X), true ) } &
  { X < 5 } &
  { existing_metafact( student, 'rehydration intravenous'(Y), true ) } &
  { Y < 5 } &
  student : 'specific test'( 'csf exam', Z ) ::= true &
  { Z < 5 }

==>
select ( 'virus of intestinal tract'(5), 'parasite of intestinal tract'(5),
        'bacterial infection of neurological system'(5), 'contact neurologist'(5) ) &
        step(4) ::= false & step(5) ::= true.

% ----- specific test done
% ----- only antibiotic done
{ read_param( modified, 4) } &
  student : antibiotic(T) ::= true &
  { T < 5 } &
  { \+ existing_metafact( student, 'rehydration intravenous'(_), true) } &
  { existing_metafact( student, 'specific test'('csf exam', _), true) }

==>
select ( 'virus of intestinal tract'(5), 'parasite of intestinal tract'(5),
        'bacterial infection of neurological system'(5), 'contact neurologist'(5) ) &
        step(4) ::= false & step(5) ::= true.

```

```

% ----- specific test done
% ----- only rehydration intravenous done
{ read_param( modified, 4 ) } &
  student : 'rehydration intravenous'(T) ::= true &
    { T < 5 } &
    { \+ existing_metafact( student, antibiotic(_), true) } &
    { existing_metafact( student, 'specific test'('csf exam', _), true) }
==>
select ( 'virus of intestinal tract'(5), 'parasite of intestinal tract'(5),
  'bacterial infection of neurological system'(5), 'contact neurologist'(5) ) &
  step(4) ::= false & step(5) ::= true.

% ----- intravenous rehydration and antibiotic done
% ----- except specific test
{ read_param( modified, 4 ) } &
  student : 'rehydration intravenous'(4) ::= true &
  student : antibiotic(4) ::= true &
  student : 'specific test'('csf exam', 4 ) ::= false

==>
select ( 'specific test'(urine, 5), 'specific test'(stool, 5),
  'specific test'('csf exam', 5), hospitalization(5), 'rehydration oral'(5) ) &
  step(4) ::= false & step(5) ::= true.

% -----Modifications 5

% ----- only specific test requested
% ----- all correct treatments done
step(5) ::= true &
  student : 'rehydration intravenous'(4) ::= true &
  student : antibiotic(4) ::= true &
  student : 'specific test'('csf exam', 5 ) ::= true &
  { write_param( modified, 5 ) }
==>
modify ( bacteria( neu ) <-& specific_tests('csf exam'),
  specific_tests('csf exam') <- neutrophils(increase, 5) & bands(increase, 5) ).

%-----Selections 6
% ----- specific test requested.
% ----- correct treatments done earlier
{ read_param(modified, 5) } &
  { existing_metafact( student, 'rehydration intravenous'(_), true) } &
  { existing_metafact( student, antibiotic(_), true) } &
  student : 'specific test'('csf exam', _ ) ::= true

```

```

==>
select ('virus of intestinal tract'(6), 'parasite of intestinal tract'(6),
       'bacterial infection of neurological system'(6), 'contact neurologist'(6) ) &
       step(5) ::= false & step(6) ::= true.

%-----TERMINATION RULES

% ----- hospitalization requested, infant only sick
student : hospitalization(_) ::= true
==>
terminate ' :
    Condition of the patient does not
    warrant hospitalization.' .

% ----- contact specialist requested,
student : 'contact specialist'(_) ::= true
==>
terminate ' :
    No reason to contact a specialist.' .

% --- no general exam requested after selection 2
step(2) ::= true &
    { \+ existing_metafact( student, 'general exam'(_), true ) }
==>
terminate ' :
    You cannot proceed further.
    You must learn the proper management of the case.' .

% --- no history requested after selection 2
step(2) ::= true &
    { \+ existing_metafact( student, 'patient history'(T), true ) }
==>
terminate ' :
    You cannot proceed further.
    You must learn the proper management of the case.' .

% ----- no general exam but interim treatment requested
student : 'interim treatment'(_) ::= true &
    { \+ existing_metafact( student, 'general exam'(_), true ) }
==>
terminate ' :
    No basis for interim treatment.
    General exam was not requested.' .

```

% --- patient history and interim treatment cannot be requested simultaneously

student : 'patient history'(T) ::= true &

student : 'interim treatment'(T) ::= true

==>

terminate ':

Without patient history,

interim treatment cannot be requested.

You must learn the proper management of the case.'.

% --- rehydration oral requested

student : 'rehydration oral'(_) ::= true

==>

terminate ':

Incorrect treatment:

oral rehydration is not sufficient.'.

% --- specific test'(stool) requested

student : 'specific test'(stool, _) ::= true

==>

terminate ':

This is the incorrect specific test.

Please consult the specialist.'.

% --- specific test'(urine) requested

student : 'specific test'(urine, _) ::= true

==>

terminate ':

This is the incorrect specific test.

Please consult the specialist.'.

% --- antibiotic requested without general tests

student : antibiotic(T) ::= true &

{ \+ existing_metafact(student, 'general tests'(_), true) }

==>

terminate ':

You cannot proceed further.

You must learn proper management of the case.'.

% --- rehydration intravenous requested without general tests

student : 'rehydration intravenous'(T) ::= true &

{ \+ existing_metafact(student, 'general tests'(_), true) }

==>

terminate ':

You cannot proceed further.

You must learn proper management of the case.'.

% --- the request of general tests must be prior to antibiotic

student : antibiotic(T) ::= true &

student : 'general tests'(T) ::= true

==>

terminate ':

Antibiotic cannot be requested
without prior general tests.'

% --- the request of general tests must be prior to rehydration intravenous

student : 'rehydration intravenous'(T) ::= true &

student : 'general tests'(T) ::= true

==>

terminate ':

Rehydration intravenous cannot be requested
without prior general tests.'

% --- only antibiotic is not sufficient

student : antibiotic(T) ::= true &

student : 'rehydration intravenous'(T) ::= false &

student : 'specific test'('csf exam', T) ::= false

==>

terminate ':

This treatment is not sufficient,
and no specific tests were requested.'

% --- only rehydration intravenous is not sufficient

student : 'rehydration intravenous'(T) ::= true &

student : antibiotic(T) ::= false &

student : 'specific test'('csf exam', T) ::= false

==>

terminate ':

This treatment is not sufficient,
and no specific tests were requested.'

% --- too long for diagnosis

step(5) ::= true &

{ \+ existing_metafact(sick_infant, vomiting(_), false) }

==>

terminate ':

The diagnostic process is too long.
The patient is suffering seriously without treatment.
You are advised to consult the specialist'.

```

% --- Incorrect diagnosis
student : 'parasite of intestinal tract'(_) ::= true
==>
terminate ':
    Incorrect diagnosis.
    Please consult the specialist. ' .

% --- Incorrect diagnosis
student : 'virus of intestinal tract'(_) ::= true
==>
terminate ':
    Incorrect diagnosis.
    Please consult the specialist. ' .

% --- only contact neurologist requested
student : 'contact neurologist'(_) ::= true &
{ \+ existing_metafact( student, 'bacterial infection of neurological system'(_), true)}
==>
terminate ':
    Correct diagnosis should also be selected.' .

% --- only correct diagnosis requested
student : 'bacterial infection of neurological system'(_) ::= true &
{ \+ existing_metafact( student, 'contact neurologist'(_), true)}

==>
terminate ':
    One more action should be done to complete the diagnosis of the case.' .

% --- correct diagnosis, but not all the treatment selected
student : 'bacterial infection of neurological system'(_) ::= true &
student : 'rehydration intravenous'(_) ::= true &
student : 'specific test'('csf exam', _) ::= true &
student : 'contact neurologist'(_) ::= true &
{ \+ existing_metafact( student, antibiotic(_), true)}
==>
terminate ':
    The correct diagnosis:
        bacterial infection of the neurological system.
    The correct interim treatments:
        contact neurologist,
        but only intravenous rehydration is not sufficient.' .

```

```

% --- correct diagnosis, but not all the treatment selected
student : 'bacterial infection of neurological system'(_) ::= true &
student : antibiotic(_) ::= true &
student : 'specific test'('csf exam', _) ::= true &
student : 'contact neurologist'(_) ::= true &
        { \+ existing_metafact( student, 'rehydration intravenous'(_), true)}
==>
terminate ':
    The correct diagnosis:
        bacterial infection of the neurological system.
    The correct interim treatments:
        contact neurologist,
        but only antibiotic is not sufficient.' .

% --- correct treatments and diagnosis
student : antibiotic(_) ::= true &
student : 'rehydration intravenous'(_) ::= true &
student : 'specific test'('csf exam', _) ::= true &
student : 'contact neurologist'(_) ::= true &
student : 'bacterial infection of neurological system'(_) ::= true
==>
terminate ':
    The correct diagnosis:
        bacterial infection of the neurological system.
    The interim treatments:
        intravenous rehydration, antibiotic,
        and contact neurologist
    Congratulations!' .

```


Knowledge Base for A Bacterial Intestinal Infection

Appendix N

Knowledge Base for A Bacterial Intestinal Infection

```

%% medic: rebase.ext.intestinal-bacterial
%% without scoring system

% ----- initial conditions
step(0) ::= true .

% ----- Selection 1
sick_infant : diarrhea(0) ::= true & step(0) ::= true
==>
select ( 'general exam'(1), 'patient history'(1), 'contact specialist'(1),
        hospitalization(1) ) &
        step(1) ::= true & step(0) ::= false .

% -----Modifications 1

%----- only general exam selected
step(1) ::= true &
    student : 'general exam'(1) ::= true &
        student : 'patient history'(1) ::= false &
        { get_value1( 'loss of weight', W ) } &
        { write_param( modified, 1 ) }
==>
modify ( bacteria( int ) <-& general_exam,
        general_exam <- pulse( high, 1 ) & behaviour( normal, 1 ) & fever( 38, 1 ) &
        'blood pressure'( low, 1 ) & 'head size'( normal, 1 ) &
        age( '13 months', 1 ) & 'loss of weight'( W, 'per cent', 1 ) &
        'head size'( normal, 1 ) & fontanel( ok, 1 ) & 'dry mouth'(1) &
        skin( normal, 1 ) ) .

% ----- patient history selected, exam - not
step(1) ::= true &
    student : 'general exam'(1) ::= false &
        student : 'patient history'(1) ::= true &
        { write_param( modified, 1 ) }

==>
modify ( bacteria( int ) <-& patient_history,
        patient_history <- diet( 'no change' ) & family( 'no similar symptoms' ) &
        'bowel movement'( normal ) & 'no previous treatment' &
        'no abdominal obstruction' ) .

```

```

% ----- patient history and exam selected
step(1) ::= true &
  student : 'general exam'(1) ::= true &
  student : 'patient history'(1) ::= true &
  { get_value( 'loss of weight', W ) } &
  { write_param( modified, 1 ) }
==>
modify ( bacteria( int ) <-& general_exam & patient_history,
  general_exam <- pulse( high, 1 ) & behaviour( normal, 1 ) & fever( 38, 1 ) &
  'blood pressure'( low, 1 ) & 'head size'( normal, 1 ) &
  age( '13 months', 1 ) & 'loss of weight'( W, 'per cent', 1 ) &
  'head size'( normal, 1 ) & fontanel( ok, 1 ) & 'dry mouth'(1) &
  skin( normal, 1 ),
  patient_history <- diet( 'no change' ) & family( 'no similar symptoms' ) &
  'bowel movement'( normal ) & 'no previous treatment' &
  'no abdominal obstruction' ) .

% ----- Selections 2

% ----- only history was requested
{ read_param( modified, 1 ) } &
  student : 'patient history'(1) ::= true &
  student : 'general exam'(1) ::= false
==>
select ( 'general tests'(2), 'general exam'(2), 'contact specialist'(2),
  hospitalization(2) ) &
  step(1) ::= false & step(2) ::= true .

% ----- only general exam was selected
{ read_param( modified, 1 ) } &
  student : 'general exam'(1) ::= true &
  student : 'patient history'(1) ::= false
==>
select ( 'general tests'(2), 'contact specialist'(2), 'patient history'(2),
  'interim treatment'(2), hospitalization(2) ) &
  step(1) ::= false & step(2) ::= true .

% ----- both general exam and patient history selected
{ read_param( modified, 1 ) } &
  student : 'general exam'(1) ::= true &
  student : 'patient history'(1) ::= true
==>
select ( 'general tests'(2), 'contact specialist'(2),
  'interim treatment'(2), hospitalization(2) ) &
  step(1) ::= false & step(2) ::= true .

```

```

% -----Modifications 2
% % % % %      For both (W =<10) and (W>10)      % % % % %
% ----- only general exam requested (history - earlier)
step(2) ::= true &
  student : 'general exam'(2) ::= true &
  student : 'general tests'(2) ::= false &
  { get_value1( 'loss of weight', W ) } &
  { write_param( modified, 2 ) }
==>
modify ( bacteria( int ) <-& general_exam,
  general_exam <- pulse( high, 2 ) & behaviour( normal, 2 ) & fever( 38, 2 ) &
  'blood pressure'( low, 2 ) & 'head size'( normal, 2 ) &
  age( '13 months', 2 ) & 'loss of weight'( W, 'per cent', 2 ) &
  'head size'( normal, 2 ) & fontanel( ok, 2 ) & 'dry mouth'(2) &
  skin( normal, 2 ) ).

% ----- general exam and tests requested (history - earlier)
step(2) ::= true &
  student : 'general exam'(2) ::= true &
  student : 'general tests'(2) ::= true &
  { get_value1( 'loss of weight', W ) } &
  { write_param( modified, 2 ) }
==>
modify ( bacteria( int ) <-& general_exam & 'general tests'( pending, 2 ),
  general_exam <- pulse( high, 2 ) & behaviour( normal, 2 ) & fever( 38, 2 ) &
  'blood pressure'( low, 2 ) & 'head size'( normal, 2 ) &
  age( '13 months', 2 ) & 'loss of weight'( W, 'per cent', 2 ) &
  'head size'( normal, 2 ) & fontanel( ok, 2 ) & 'dry mouth'(2) &
  skin( normal, 2 ) ).

% ----- patient history selected, tests - not (exam - earlier)
step(2) ::= true &
  student : 'patient history'(2) ::= true &
  student : 'general tests'(2) ::= false &
  student : hospitalization(2) ::= false &
  student : 'interim treatment'(2) ::= false &
  { write_param( modified, 2 ) }

==>
modify ( bacteria( int ) <-& patient_history,
  patient_history <- diet( 'no change' ) & family( 'no similar symptoms' ) &
  'bowel movement'( normal ) & 'no previous treatment' &
  'no abdominal obstruction' ).

```

```

% ----- history and general tests requested (exam - earlier)
step(2) ::= true &
  student : 'patient history'(2) ::= true &
    student : 'general tests'(2) ::= true &
    student : hospitalization(2) ::= false &
  student : 'interim treatment'(2) ::= false &
  { write_param( modified, 2 ) }
==>
modify ( bacteria( int ) <-& patient_history & 'general tests'( pending, 2 ),
  patient_history <- diet( 'no change' ) & family( 'no similar symptoms' ) &
    'bowel movement'( normal ) & 'no previous treatment' &
    'no abdominal obstruction' ) .

%%%%%%%%%      general exam and history done      %%%%%%%%%%
% ----- general tests requested
% ----- interim treatment requested, or not
step(2) ::= true &
  student : 'general exam'(1) ::= true &
  student : 'patient history'(1) ::= true &
  student : 'general tests'(2) ::= true &
  student : hospitalization(2) ::= false &
  { write_param( modified, 2 ) }
==>
modify ( bacteria( int ) <-& blood_test & urine_test,
  blood_test <- 'red cell'( normal, 2 ) & 'white cell'( normal, 2 ) &
    'cell smear'( normal, 2 ),
  urine_test <- ketones( elevated, 2 ) & 'blood in urine'( absent, 2 ) &
    sugar( absent, 2 ) & proteins( absent, 2 ) ) .

% ----- interim treatment requested, no general tests
step(2) ::= true &
  student : 'interim treatment'(2) ::= true &
  student : hospitalization(2) ::= false &
  { \+ existing_metafact( student, 'general tests'(_), true ) } &
  { write_param( modified, 2 ) }
==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
  visible_symptoms(int, b1) <- diarrhea(2) & vomiting(2) &
    'refusal to eat'(2) & irritability(neutral, 2 ) ) .

```

```

%%c%c%c%c% existing_metafact( sick_infant, 'loss of weight'(W > 10) ) %c%c%c%c%
%%c%c%c%c% [general_exam] %c%c%c%c%
% ----- hospitalization, history and general tests requested
% ----- pending on general tests
step(2) ::= true &
    student : 'general_exam'(1) ::= true &
    student : hospitalization(2) ::= true &
    student : 'general_tests'(2) ::= true &
    student : 'patient_history'(2) ::= true &
    { write_param( modified, 2 ) }
==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & 'general_tests'( pending, 2),
    visible_symptoms(int, b1) <- diarrhea(2) & vomiting(2) &
    'refusal to eat'(2) & irritability(neutral, 2) ).

% ----- hospitalization and patient history requested
% ----- not general tests
step(2) ::= true &
    student : hospitalization(2) ::= true &
    student : 'patient_history'(2) ::= true &
    student : 'general_tests'(2) ::= false &
    { write_param( modified, 2 ) }
==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
    visible_symptoms(int, b1) <- diarrhea(2) & vomiting(2) &
    'refusal to eat'(2) & irritability(neutral, 2) ).

% ----- hospitalization requested only
% ----- no general tests and interim treatment
step(2) ::= true &
    student : hospitalization(2) ::= true &
    student : 'interim_treatment'(2) ::= false &
    student : 'general_tests'(2) ::= false &
    student : 'patient_history'(2) ::= false &
    { write_param( modified, 2 ) }

```

```

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
        visible_symptoms(int, b1) <- diarrhea(2) & vomiting(2) &
        'refusal to eat'(2) & irritability(neutral, 2) ).

%%%%%%%% [general exam & history] %%%%%%%%%
% ----- hospitalization and general tests requested (no pending on tests)
% ----- interim treatment also requested
step(2) ::= true &
  sick_infant : 'loss of weight'( W, 'per cent', _ ) ::= true & { W > 10 } &
  student : 'general exam'(1) ::= true &
  student : 'patient history'(1) ::= true &
  student : hospitalization(2) ::= true &
  student : 'general tests'(2) ::= true &
  student : 'interim treatment'(2) ::= true &
  { write_param( modified, 2 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & blood_test & urine_test,
        visible_symptoms(int, b1) <- diarrhea(2) & vomiting(2) &
        'refusal to eat'(2) & irritability(neutral, 2),
        blood_test <- 'red cell'( normal, 2 ) & 'white cell'( normal, 2 ) &
        'cell smear'( normal, 2 ),
        urine_test <- ketones( elevated, 2 ) & 'blood in urine'( absent, 2 ) &
        sugar( absent, 2 ) & proteins( absent, 2 ) ).

% ----- hospitalization and general tests requested (no pending on tests)
% ----- interim treatment not
step(2) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _ ) ::= true & { W > 10 } &
  student : hospitalization(2) ::= true &
  student : 'general tests'(2) ::= true &
  student : 'interim treatment'(2) ::= false &
  student : 'general exam'(1) ::= true &
  student : 'patient history'(1) ::= true &
  { write_param( modified, 2 ) }

```

```

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & blood_test & urine_test,
        visible_symptoms(int, b1) <- diarrhea(2) & vomiting(2) &
        'refusal to eat'(2) & irritability(neutral, 2),
        blood_test <- 'red cell'( normal, 2 ) & 'white cell'( normal, 2 ) &
        'cell smear'( normal, 2 ),
        urine_test <- ketones( elevated, 2 ) & 'blood in urine'( absent, 2 ) &
        sugar( absent, 2 ) & proteins( absent, 2 ) ) .

% ----- hospitalization and interim treatment requested
% ----- no general tests
step(2) ::= true &
    sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
    student : hospitalization(2) ::= true &
    student : 'interim treatment'(2) ::= true &
    student : 'general tests'(2) ::= false &
    student : 'general exam'(1) ::= true &
    student : 'patient history'(1) ::= true &
    { write_param( modified, 2 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
        visible_symptoms(int, b1) <- diarrhea(2) & vomiting(2) &
        'refusal to eat'(2) & irritability(neutral, 2) ) .

% ----- hospitalization requested only
% ----- no general tests and interim treatment
step(2) ::= true &
    sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
    student : hospitalization(2) ::= true &
    student : 'interim treatment'(2) ::= false &
    student : 'general tests'(2) ::= false &
    student : 'general exam'(1) ::= true &
    student : 'patient history'(1) ::= true &
    { write_param( modified, 2 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
        visible_symptoms(int, b1) <- diarrhea(2) & vomiting(2) &
        'refusal to eat'(2) & irritability(neutral, 2) ) .

```



```

%----- Selections 3

% ----- general exam, history - requested, no tests, no treatment
{ read_param( modified, 2 ) } &
  student : 'general tests'(2) ::= false &
  student : hospitalization(2) ::= false &
  { existing_metafact( student, 'patient history'(_), true ) } &
  { existing_metafact( student, 'general exam'(_), true ) } &
  { \+ existing_metafact( student, 'interim treatment'(_), true ) }
==>
select ( 'general tests'(3), 'contact specialist'(3), 'interim treatment'(3),
        hospitalization(3) ) &
  step(2) ::= false & step(3) ::= true .

%----- history, exam and general tests requested, no interim treatment
{ read_param( modified, 2 ) } &
  student : 'general tests'(2) ::= true &
  student : hospitalization(2) ::= false &
  { existing_metafact( student, 'general exam'(_), true ) } &
  { existing_metafact( student, 'patient history'(_), true ) } &
  { \+ existing_metafact( student, 'interim treatment'(_), true ) }
==>
select ( 'specific test'( stool, 3 ), 'specific test'('csf exam', 3 ),
        'specific test'( 'blood culture', 3 ),
        hospitalization(3), 'interim treatment'(3) ) &
  step(2) ::= false & step(3) ::= true .

% ----- interim treatment requested, general exam and history done
% ----- no general tests
{ read_param( modified, 2 ) } &
  student : 'interim treatment'(2) ::= true &
  student : hospitalization(2) ::= false &
  { existing_metafact( student, 'general exam'(_), true ) } &
  { existing_metafact( student, 'patient history'(_), true ) } &
  { \+ existing_metafact( student, 'general tests'(_), true ) }
==>
select ( hospitalization(3), 'rehydration oral'(3), antibiotic(3),
        'rehydration intravenous'(3), 'general tests'(3) ) &
  step(2) ::= false & step(3) ::= true .

```

```

% ----- general tests and interim treatment requested (history, exam earlier)
{ read_param( modified, 2 ) } &
  student : 'general tests'(2) ::= true &
  student : 'interim treatment'(2) ::= true &
  student : hospitalization(2) ::= false &
  { existing_metafact( student, 'general exam'(_), true ) } &
  { existing_metafact( student, 'patient history'(_), true ) }
==>
select ( 'specific test'( stool, 2 ), 'specific test'( 'csf exam', 3 ),
  'specific test'( 'blood culture', 3 ), hospitalization(3),
  'rehydration oral'(3), 'rehydration intravenous'(3),
  antibiotic(3), 'contact specialist'(3) ) &
  step(2) ::= false & step(3) ::= true .

%%%%%%%%% existing_metafact( sick_infant, 'loss of weight'(W > 10) ) %%%%%%%%%%
%%%%%%%%% %%%%%%%%%%

% ----- hospitalization requested only
% ----- no general tests and patient history
{ read_param( modified, 2 ) } &
  student : hospitalization(2) ::= true &
  student : 'interim treatment'(2) ::= false &
  student : 'general tests'(2) ::= false &
  { \+ existing_metafact( student, 'patient history'(_), true ) }
==>
select ( 'patient history'(3), 'general tests'(3), 'contact specialist'(3),
  'interim treatment'(3) ) &
  step(2) ::= false & step(3) ::= true .

% ----- hospitalization and patient history requested
% ----- no general tests
{ read_param( modified, 2 ) } &
  student : hospitalization(2) ::= true &
  student : 'patient history'(2) ::= true &
  student : 'general tests'(2) ::= false
==>
select ( 'general tests'(3), 'interim treatment'(3), 'contact specialist'(3) ) &
  step(2) ::= false & step(3) ::= true .

% ----- hospitalization, patient history, and general tests requested
{ read_param( modified, 2 ) } &
  student : hospitalization(2) ::= true &
  student : 'general tests'(2) ::= true &
  student : 'patient history'(2) ::= true

```

```

==>
select ( 'specific test'( stool, 3 ), 'specific test'('csf exam', 3 ),
        'specific test'( 'blood culture', 3 ),
        'interim treatment'(3), 'contact specialist'(3) ) &
        step(2) ::= false & step(3) ::= true .

% ----- hospitalization, interim treatment, and general tests requested
{ read_param( modified, 2 ) } &
  student : hospitalization(2) ::= true &
  student : 'general tests'(2) ::= true &
  student : 'interim treatment'(2) ::= true &
  { existing_metafact( student, 'patient history'(1), true ) }
==>
select ( 'specific test'( stool, 3 ), 'specific test'('csf exam', 3 ),
        'specific test'( 'blood culture', 3 ), 'rehydration oral'(3),
        'rehydration intravenous'(3), antibiotic(3), 'contact specialist'(3) ) &
        step(2) ::= false & step(3) ::= true .

% ----- hospitalization and general tests requested
% ----- interim treatment not
{ read_param( modified, 2 ) } &
  student : hospitalization(2) ::= true &
  student : 'general tests'(2) ::= true &
  student : 'interim treatment'(2) ::= false &
  { existing_metafact( student, 'patient history'(1), true ) }
==>
select ( 'specific test'( stool, 3 ), 'specific test'('csf exam', 3 ),
        'specific test'( 'blood culture', 3 ),
        'interim treatment'(3), 'contact specialist'(3) ) &
        step(2) ::= false & step(3) ::= true .

% ----- hospitalization and interim treatment requested
% ----- no general tests
{ read_param( modified, 2 ) } &
  student : hospitalization(2) ::= true &
  student : 'interim treatment'(2) ::= true &
  student : 'general tests'(2) ::= false &
  { existing_metafact( student, 'patient history'(1), true ) }
==>
select ( 'general tests'(3), 'contact specialist'(3), 'rehydration oral'(3),
        'rehydration intravenous'(3), antibiotic(3) ) &
        step(2) ::= false & step(3) ::= true .

```

```

% ----- hospitalization requested only
% ----- no general tests and interim treatment
{ read_param( modified, 2 ) } &
  student : hospitalization(2) ::= true &
  student : 'interim treatment'(2) ::= false &
  student : 'general tests'(2) ::= false &
  { existing_metafact( student, 'patient history'(1), true ) }

==>
select ( 'general tests'(3), 'contact specialist'(3), 'interim treatment'(3) ) &
  step(2) ::= false & step(3) ::= true .

% -----Modifications 3

%%%%%%%%%    [patient history]    [general exam]    { W =< 10 }    %%%%%%%%%%
%%%%%%%%%    [general exam]      [patient history]   { W =< 10 }    %%%%%%%%%%

% ----- interim treatment and general tests requested
% ----- no pending on general tests
% ----- (general exam and history done)
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W =< 10 } &
  student : 'interim treatment'(3) ::= true &
  student : 'general tests'(3) ::= true &
  { \+ existing_metafact( student, 'specific test'(_, _), true ) } &
  { \+ existing_metafact( student, hospitalization(_), true ) } &
  { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & blood_test & urine_test,
  visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
  'refusal to eat'(3) & irritability(neutral, 3),
  blood_test <- 'red cell'( normal, 3 ) & 'white cell'( normal, 3 ) &
  'cell smear'( normal, 3 ),
  urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
  sugar( absent, 3 ) & proteins( absent, 3 ) ) .

% ----- interim treatment requested, no general tests
% ----- (general exam and history done)
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W =< 10 } &
  student : 'interim treatment'(3) ::= true &
  { \+ existing_metafact( student, 'general tests'(_), true ) } &
  { \+ existing_metafact( student, hospitalization(_), true ) } &
  { write_param( modified, 3 ) }

```

```

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
        visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
        'refusal to eat'(3) & irritability(neutral, 3) ).

% ----- only general tests requested, no treatment
step(3) ::= true &
    sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W =< 10 } &
    student : 'general tests'(3) ::= true &
    { \+ existing_metafact( student, 'interim treatment'(_), true ) } &
    { \+ existing_metafact( student, hospitalization(_), true ) } &
    { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& blood_test & urine_test,
        blood_test <- 'red cell'( normal, 3 ) & 'white cell'( normal, 3 ) &
        'cell smear'( normal, 3 ),
        urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
        sugar( absent, 3 ) & proteins( absent, 3 ) ).

%%%%%%%% [exam & history] [general tests] { W =< 10 } %%%%%%%%%
% ----- NO pending on general tests
% ----- specific test and interim treatment requested
step(3) ::= true &
    sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W =< 10 } &
    student : 'specific test'( stool, 3 ) ::= true &
    student : 'interim treatment'(3) ::= true &
    { existing_metafact( student, 'general tests'(_), true ) } &
    { \+ existing_metafact( sick_infant, 'general tests'( pending, 2 ), true ) } &
    { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & specific_tests( stool ),
        visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
        irritability(high, 3),
        specific_tests( stool ) <- blood( absent, 3 ) & 'bacterial culture'(positive, 3)
        & parasites( absent, 3 ) & viral( negative, 3 ) ).

% ----- only specific test requested, no treatment
step(3) ::= true &
    sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W =< 10 } &
    student : 'specific test'( stool, 3 ) ::= true &
    student : 'interim treatment'(3) ::= false &
    { existing_metafact( student, 'general tests'(_), true ) } &
    { \+ existing_metafact( sick_infant, 'general tests'( pending, 2 ), true ) } &
    { write_param( modified, 3 ) }

```

```

==>
modify ( bacteria( int ) <-& specific_tests( stool ),
        specific_tests( stool ) <- blood( absent, 3 ) & 'bacterial culture'(positive, 3)
        & parasites( absent, 3 ) & viral( negative, 3 ) ).

% ----- only treatment requested, no specific test
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W =< 10 } &
  student : 'interim treatment'(3) ::= true &
  student : 'specific test'( stool, 3 ) ::= false &
  { existing_metafact( student, 'general tests'(_), true ) } &
  { \+ existing_metafact( sick_infant, 'general tests'( pending, 2 ), true ) } &
  { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
        visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
        irritability(high, 3) ).

%%%%%%%%% [general exam & history] [interim treatment] { W =< 10 }
%%%%%%%%%
% ----- general tests requested
step(3) ::= true &
  student : 'general tests'(3) ::= true &
  student : 'interim treatment'(2) ::= true &
  { \+ existing_metafact( student, hospitalization(_), true ) } &
  { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& blood_test & urine_test,
        blood_test <- 'red cell'(normal, 3) & 'white cell'( normal, 3 ) &
        'cell smear'( normal, 3 ),
        urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
        'sugar( absent, 3 ) & proteins( absent, 3 ) ).

%%%%%%%%% existing_metafact( sick_infant, 'loss of weight'(W =<10) )
%%%%%%%%%
%%%%%%%%% [general exam & history] [general tests & interim treatment]
%%%%%%%%%
% ----- correct specific test and correct treatment
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W =< 10 } &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'rehydration oral'(3) ::= true &
  { write_param( modified, 3 ) }

```

```

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & specific_tests( stool ),
        visible_symptoms(int, b1) <- not diarrhea(3) & not vomiting(3) &
        irritability(neutral, 3 ),
        specific_tests( stool ) <- blood( absent,3 ) & 'bacterial culture'(positive, 3)
        & parasites( absent, 3 ) & viral( negative, 3 ) ).

% ----- correct treatment without specific test
step(3) ::= true &
    sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W =< 10 } &
    student : 'specific test'( stool, 3 ) ::= false &
    student : 'rehydration oral'(3) ::= true &
    { existing_metafact( student, 'general tests'(_), true ) } &
    { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
        visible_symptoms(int, b1) <- not diarrhea(3) & not vomiting(3) &
        irritability(neutral, 3 ) ).

% ----- stool test requested only, no rehydration oral
step(3) ::= true &
    sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W =< 10 } &
    student : 'specific test'( stool, 3 ) ::= true &
    student : 'rehydration oral'(3) ::= false &
    { existing_metafact( student, 'general tests'(_), true ) } &
    { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& specific_tests( stool ),
        specific_tests( stool ) <- blood( absent,3 ) & 'bacterial culture'(positive, 3)
        & parasites( absent, 3 ) & viral( negative, 3 ) ).

%%%%%%%%% [general exam] [history & general tests] { W =< 10 }
%%%%%%%%%
%%%%%%%%% [patient history] [exam & general tests] { W =< 10 }
%%%%%%%%%

% ----- only interim treatment requested
% ----- (general tests : pending, general exam and history done)
step(3) ::= true &
    sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W =< 10 } &
    sick_infant : 'general tests'( pending, 2 ) ::= true &
    student : 'interim treatment'( 3 ) ::= true &
    { \+ existing_metafact( student, 'specific test'(_), true ) } &
    { write_param( modified, 3 ) }

```

```

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & blood_test & urine_test,
        visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
        'refusal to eat'(3) & irritability(neutral, 3),
        blood_test <- 'red cell'( normal, 3 ) & 'white cell'( normal, 3 ) &
        'cell smear'( normal, 3 ),
        urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
        sugar( absent, 3 ) & proteins( absent, 3 ) ).

% ----- only specific test, no treatment
% ----- general tests(pending)
step(3) ::= true &
    sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W =< 10 } &
    student : 'specific test'( stool, 3 ) ::= true &
    sick_infant : 'general tests'( pending, 2 ) ::= true &
    { \+ existing_metafact( student, 'interim treatment'(_), true ) } &
    { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& blood_test & urine_test & specific_tests( stool ),
        blood_test <- 'red cell'( normal, 3 ) & 'white cell'( normal, 3 ) &
        'cell smear'( normal, 3 ),
        urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
        sugar( absent, 3 ) & proteins( absent, 3 ),
        specific_tests( stool ) <- blood( absent, 3 ) & 'bacterial culture'(positive, 3)
        & parasites( absent, 3 ) & viral( negative, 3 ) ).

% ----- specific test and interim treatment requested
% ----- general tests(pending)
step(3) ::= true &
    sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W =< 10 } &
    student : 'specific test'( stool, 3 ) ::= true &
    student : 'interim treatment'(3) ::= true &
    sick_infant : 'general tests'( pending, 2 ) ::= true &
    { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & blood_test & urine_test
        & specific_tests( stool ),
        visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
        irritability(high, 3),
        blood_test <- 'red cell'( normal, 3 ) & 'white cell'( normal, 3 ) &
        'cell smear'( normal, 3 ),
        urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
        sugar( absent, 3 ) & proteins( absent, 3 ),
        specific_tests( stool ) <- blood( absent, 3 ) & 'bacterial culture'(positive, 3)
        & parasites( absent, 3 ) & viral( negative, 3 ) ).

```



```

%%%%%%      existing_metafact( sick_infant, 'loss of weight'(W > 10) )
      %%%%'%%
%%%%%%      [exam & history]      [hospitalization & general tests]      { W > 10 }
      %%%%'%%
% ----- NO pending on general tests
% ----- all specific tests and interim treatment requested
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'specific test'( 'blood culture', 3 ) ::= true &
  student : 'interim treatment'(3) ::= true &
  { existing_metafact( student, 'general tests'(_), true ) } &
  { \+ existing_metafact( sick_infant, 'general tests'( pending, 2 ), true ) } &
  { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & specific_tests( stool )
      & specific_tests( 'blood culture' ),
      visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
      irritability(high, 3),
      specific_tests( stool ) <- blood( absent,3 ) & 'bacterial culture'(positive, 3)
      & parasites( absent, 3 ) & viral( negative, 3 ),
      specific_tests( 'blood culture' ) <- 'blood culture'( positive, 3 ) ).

% ----- only stool test and interim treatment requested
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'specific test'( 'blood culture', 3 ) ::= false &
  student : 'interim treatment'(3) ::= true &
  { existing_metafact( student, 'general tests'(_), true ) } &
  { \+ existing_metafact( sick_infant, 'general tests'( pending, 2 ), true ) } &
  { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & specific_tests( stool ),
      visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
      irritability(high, 3),
      specific_tests( stool ) <- blood( absent,3 ) & 'bacterial culture'(positive, 3)
      & parasites( absent, 3 ) & viral( negative, 3 ) ).

```

```

% ----- only blood culture test and interim treatment requested
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'specific test'( 'blood culture', 3 ) ::= true &
  student : 'specific test'( stool, 3 ) ::= false &
  student : 'interim treatment'(3) ::= true &
  { existing_metafact( student, 'general tests'(_), true ) } &
  { \+ existing_metafact( sick_infant, 'general tests'( pending, 2 ), true ) } &
  { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) &
  specific_tests( 'blood culture' ),
  visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
  irritability(high, 3),
  specific_tests( 'blood culture' ) <- 'blood culture'( positive, 3 ) ).

% ----- all specific tests requested, no treatment
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'specific test'( 'blood culture', 3 ) ::= true &
  { existing_metafact( student, 'general tests'(_), true ) } &
  { \+ existing_metafact( sick_infant, 'general tests'( pending, 2 ), true ) } &
  { \+ existing_metafact( student, 'interim treatment'(_), true ) } &
  { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& specific_tests( stool ) &
  specific_tests( 'blood culture' ),
  specific_tests( stool ) <- blood( absent,3 ) & 'bacterial culture'(positive, 3)
  & parasites( absent, 3 ) & viral( negative, 3 ),
  specific_tests( 'blood culture' ) <- 'blood culture'( positive, 3 ) ).

% ----- only stool tests requested, no treatment
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'specific test'( 'blood culture', 3 ) ::= false &
  { existing_metafact( student, 'general tests'(_), true ) } &
  { \+ existing_metafact( sick_infant, 'general tests'( pending, 2 ), true ) } &
  { \+ existing_metafact( student, 'interim treatment'(_), true ) } &
  { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& specific_tests( stool ),
  specific_tests( stool ) <- blood( absent,3 ) & 'bacterial culture'(positive, 3)
  & parasites( absent, 3 ) & viral( negative, 3 ) ).

```

```

% ----- only blood culture tests requested, no treatment
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'specific test'( 'blood culture', 3 ) ::= true &
  student : 'specific test'( stool, 3 ) ::= false &
  { existing_metafact( student, 'general tests'(_), true ) } &
  { \+ existing_metafact( sick_infant, 'general tests'( pending, 2 ), true ) } &
  { \+ existing_metafact( student, 'interim treatment'(_), true ) } &
  { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& specific_tests( 'blood culture' ),
        specific_tests( 'blood culture' ) <- 'blood culture'( positive, 3 ) ).

% ----- only interim treatment requested
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'interim treatment'( 3 ) ::= true &
  student : 'general tests'( 2 ) ::= true &
  { \+ existing_metafact( sick_infant, 'general tests'( pending, 2 ), true ) } &
  { \+ existing_metafact( student, 'specific test'(_,_), true ) } &
  { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
        visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
        'refusal to eat'(3) & irritability(neutral, 3) ).

%%%%%%%% [exam & history] [hospitalization & interim treatment] {W>10}
%%%%%%%%

% ----- only general tests requested, treatment earlier
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'general tests'( 3 ) ::= true &
  student : 'interim treatment'( 2 ) ::= true &
  { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& blood_test & urine_test,
        blood_test <- 'red cell'( normal, 3 ) & 'white cell'( normal, 3 ) &
        'cell smear'( normal, 3 ),
        urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
        sugar( absent, 3 ) & proteins( absent, 3 ) ).

```

```

% % % % % [general exam & history] [general tests & interim treatment]
% % % % %
% ----- all correct specific test and all correct treatments
step(3) ::= true &
  sick_infant : 'loss of weight'( W, 'per cent', _ ) ::= true & { W > 10 } &
  student : 'specific test'( stool, 3 ) ::= true &
    student : 'specific test'( 'blood culture', 3 ) ::= true &
    student : hospitalization(3) ::= true &
    student : 'rehydration intravenous'(3) ::= true &
  student : antibiotic(3) ::= true &
    student : 'general tests'(2) ::= true &
    student : 'interim treatment'(2) ::= true &
    { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & specific_tests( stool )
  & specific_tests( 'blood culture' ),
  visible_symptoms(int, b1) <- not diarrhea(3) & not vomiting(3) &
  irritability(neutral, 3),
  specific_tests( stool ) <- blood( absent,3 ) & 'bacterial culture'(positive, 3)
  & parasites( absent, 3 ) & viral( negative, 3 ),
  specific_tests( 'blood culture' ) <- 'blood culture'( positive, 3 ) ).

% ----- stool test and all correct treatments
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _ ) ::= true & { W > 10 } &
  student : 'specific test'( stool, 3 ) ::= true &
    student : 'specific test'( 'blood culture', 3 ) ::= false &
    student : hospitalization(3) ::= true &
    student : 'rehydration intravenous'(3) ::= true &
    student : antibiotic(3) ::= true &
    { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & specific_tests( stool ),
  visible_symptoms(int, b1) <- not diarrhea(3) & not vomiting(3) &
  irritability(neutral, 3),
  specific_tests( stool ) <- blood( absent,3 ) & 'bacterial culture'(positive, 3)
  & parasites( absent, 3 ) & viral( negative, 3 ) ).

```

```

%----- blood culture specific test and all correct treatments
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'specific test'( 'blood culture', 3 ) ::= true &
  student : 'specific test'( stool, 3 ) ::= false &
  student : hospitalization(3) ::= true &
  student : 'rehydration intravenous'(3) ::= true &
  student : antibiotic(3) ::= true &
{ write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) &
  specific_tests( 'blood culture' ),
  visible_symptoms(int, b1) <- not diarrhea(3) & not vomiting(3) &
  irritability(neutral, 3 ),
  specific_tests( 'blood culture' ) <- 'blood culture'( positive, 3 ) ).

% ----- all correct specific test and correct treatment
% ----- except antibiotic and rehydration intravenous
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'specific test'( 'blood culture', 3 ) ::= true &
  student : hospitalization(3) ::= true &
  student : 'rehydration intravenous'(3) ::= false &
  student : antibiotic(3) ::= false &
{ write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& specific_tests( stool )
  & specific_tests( 'blood culture' ),
  specific_tests( stool ) <- blood( absent,3 ) & 'bacterial culture'(positive, 3)
  & parasites( absent, 3 ) & viral( negative, 3 ),
  specific_tests( 'blood culture' ) <- 'blood culture'( positive, 3 ) ).

% ----- stool test and correct treatment
% ----- except blood culture and antibiotic and rehydration intravenous
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W >10 } &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'specific test'( 'blood culture', 3 ) ::= false &
  student : hospitalization(3) ::= true &
  student : 'rehydration intravenous'(3) ::= false &
  student : antibiotic(3) ::= false &
{ write_param( modified, 3 ) }

```

```

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & specific_tests( stool ),
        visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
        irritability(neutral, 3 ),
        specific_tests( stool ) <- blood( absent, 3 ) & 'bacterial culture'(positive, 3)
        & parasites( absent, 3 ) & viral( negative, 3 ) ).

% ----- blood culture test and correct treatment
% ----- except stool and rehydration intravenous
step(3) ::= true &
    sick_infant : 'loss of weight'(W, 'per cent', _ ) ::= true & { W > 10 } &
    student : 'specific test'( 'blood culture', 3 ) ::= true &
    student : 'specific test'( stool, 3 ) ::= false &
    student : hospitalization(3) ::= true &
    student : 'rehydration intravenous'(3) ::= false &
    student : antibiotic(3) ::= false &
{ write_param( modified, 3 ) }
==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) &
        specific_tests( 'blood culture' ),
        visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
        irritability(neutral, 3 ),
        specific_tests( 'blood culture' ) <- 'blood culture'( positive, 3 ) ).

% ----- all correct treatments without specific test
step(3) ::= true &
    sick_infant : 'loss of weight'(W, 'per cent', _ ) ::= true & { W > 10 } &
    student : hospitalization(3) ::= true &
    student : antibiotic(3) ::= true &
    student : 'rehydration intravenous'(3) ::= true &
    student : 'specific test'( stool, 3 ) ::= false &
    student : 'specific test'( 'blood culture', 3 ) ::= false &
{ write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
        visible_symptoms(int, b1) <- not diarrhea(3) & not vomiting(3) &
        irritability(neutral, 3 ) ).

```

```

% ----- hospitalization requested
% ----- without specific test and rehydration intravenous
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : hospitalization(3) ::= true &
  student : antibiotic(3) ::= false &
  student : 'rehydration intravenous'(3) ::= false &
    { \+ existing_metafact( student, 'specific test'( stool, _), true ) } &
    { \+ existing_metafact( student, 'specific test'( 'blood culture', _), true ) } &
    { existing_metafact( student, 'general tests'(_), true ) } &
    { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
  visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
  irritability(neutral, 3 ) ).

%%%%%%%% [general exam & history] [interim treatment] %%%%%%%%%
% ----- hospitalization and general tests requested
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : hospitalization(3) ::= true &
  student : 'general tests'(3) ::= true &
  student : 'interim treatment'(2) ::= true &
    { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & blood_test & urine_test,
  visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
  'refusal to eat'(3) & irritability(neutral, 3),
  blood_test <- 'red cell'( normal, 3 ) & 'white cell'( normal, 3 ) &
  'cell smear'( normal, 3 ),
  urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
  sugar( absent, 3 ) & proteins( absent, 3 ) ).

% ----- hospitalization requested only
% ----- no general tests
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : hospitalization(3) ::= true &
  student : 'general tests'(3) ::= false &
  student : 'interim treatment'(2) ::= true &
    { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
  visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
  'refusal to eat'(3) & irritability(neutral, 3 ) ).

```

```

% % % % % [general exam & history] [general tests] % % % % %
% ----- hospitalization and both specific tests requested
% ----- also interim treatment requested
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  { \+ existing_metafact( sick_infant, 'general tests'( pending, 2 ), true ) } &
  student : hospitalization(3) ::= true &
    student : 'specific test'( 'blood culture', 3 ) ::= true &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'interim treatment'(3) ::= true &
    { write_param( modified, 3 ) }
==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & specific_tests( stool ) &
  specific_tests( 'blood culture' ),
  visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
  'refusal to eat'(3) & irritability(neutral, 3),
  specific_tests( stool ) <- blood( absent, 3 ) & 'bacterial culture'(positive, 3)
  & parasites( absent, 3 ) & viral( negative, 3 ),
  specific_tests( 'blood culture' ) <- 'blood culture'( positive, 3 ) ).

% ----- hospitalization and only stool test requested
% ----- also interim treatment requested
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  { \+ existing_metafact( sick_infant, 'general tests'( pending, 2 ), true ) } &
  student : hospitalization(3) ::= true &
  student : 'specific test'( stool, 3 ) ::= true &
    student : 'specific test'( 'blood culture', 3 ) ::= false &
  student : 'interim treatment'(3) ::= true &
    { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & specific_tests( stool ),
  visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
  'refusal to eat'(3) & irritability(neutral, 3),
  specific_tests( stool ) <- blood( absent, 3 ) & 'bacterial culture'(positive, 3)
  & parasites( absent, 3 ) & viral( negative, 3 ) ).

```



```

% ----- hospitalization and only blood culture test requested
% ----- also interim treatment requested
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  { \+ existing_metafact( sick_infant, 'general tests'( pending, 2 ), true ) } &
  student : hospitalization(3) ::= true &
    student : 'specific test'( 'blood culture', 3 ) ::= true &
  student : 'specific test'( stool, 3 ) ::= false &
  student : 'interim treatment'(3) ::= true &
  { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) &
  specific_tests( 'blood culture' ),
  visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
  'refusal to eat'(3) & irritability(neutral, 3),
  specific_tests( 'blood culture' ) <- 'blood culture'( positive, 3 ) ).

% ----- hospitalization and both specific tests requested
% ----- interim treatment not
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  { \+ existing_metafact( sick_infant, 'general tests'( pending, 2 ), true ) } &
  student : hospitalization(3) ::= true &
    student : 'specific test'( 'blood culture', 3 ) ::= true &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'interim treatment'(3) ::= false &
  { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & specific_tests( stool ) &
  specific_tests( 'blood culture' ),
  visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
  'refusal to eat'(3) & irritability(neutral, 3),
  specific_tests( stool ) <- blood( absent, 3 ) & 'bacterial culture'(positive, 3)
  & parasites( absent, 3 ) & viral( negative, 3 ),
  specific_tests( 'blood culture' ) <- 'blood culture'( positive, 3 ) ).

```

```

% ----- hospitalization and only stool test requested
% ----- interim treatment not
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  { \+ existing_metafact( sick_infant, 'general tests'( pending, 2 ), true ) } &
  student : hospitalization(3) ::= true &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'specific test'( 'blood culture', 3 ) ::= false &
  student : 'interim treatment'(3) ::= false &
  { write_param( modified, 3 ) }
==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & specific_tests( stool ),
  visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
  'refusal to eat'(3) & irritability(neutral, 3),
  specific_tests( stool ) <- blood( absent,3 ) & 'bacterial culture'(positive, 3)
  & parasites( absent, 3 ) & viral( negative, 3 ) ).

% ----- hospitalization and only blood culture test requested
% ----- interim treatment not
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  { \+ existing_metafact( sick_infant, 'general tests'( pending, 2 ), true ) } &
  student : hospitalization(3) ::= true &
  student : 'specific test'( 'blood culture', 3 ) ::= true &
  student : 'specific test'( stool, 3 ) ::= false &
  student : 'interim treatment'(3) ::= false &
  { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) &
  specific_tests( 'blood culture' ),
  visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
  'refusal to eat'(3) & irritability(neutral, 3),
  specific_tests( 'blood culture' ) <- 'blood culture'( positive, 3 ) ).

% ----- hospitalization and interim treatment requested
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  { \+ existing_metafact( sick_infant, 'general tests'( pending, 2 ), true ) } &
  student : hospitalization(3) ::= true &
  student : 'interim treatment'(3) ::= true &
  { \+ existing_metafact( student, 'specific test'(_, _), true ) } &
  { write_param( modified, 3 ) }

```

```

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
        visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
        'refusal to eat'(3) & irritability(neutral, 3) ).

% ----- hospitalization requested only
% ----- no general tests
step(3) ::= true &
    sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
    { \+ existing_metafact( sick_infant, 'general tests'( pending, 2 ), true ) } &
    student : hospitalization(3) ::= true &
    student : 'interim treatment'(3) ::= false &
    { \+ existing_metafact( student, 'specific test'(_, _), true ) } &
    { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
        visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
        'refusal to eat'(3) & irritability(neutral, 3) ).

%%%%%%%%% [exam & history] [hosp. & general tests & interim treatment]
%%%%%%%%%

% ----- all correct specific test and intravenous
step(3) ::= true &
    sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
    student : 'specific test'( stool, 3 ) ::= true &
    student : 'specific test'( 'blood culture', 3 ) ::= true &
    student : antibiotic(3) ::= true &
    student : 'rehydration intravenous'(3) ::= true &
    student : hospitalization(2) ::= true &
    { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & specific_tests( stool )
        & specific_tests( 'blood culture' ).
        visible_symptoms(int, b1) <- not diarrhea(3) & not vomiting(3) &
        irritability(neutral, 3 ),
        specific_tests( stool ) <- blood( absent, 3 ) & 'bacterial culture'(positive, 3)
        & parasites( absent, 3 ) & viral( negative, 3 ),
        specific_tests( 'blood culture' ) <- 'blood culture'( positive, 3 ) ).

```

```

% ----- only stool test and intravenous
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'specific test'( stool, 3 ) ::= true &
    student : 'specific test'( 'blood culture', 3 ) ::= false &
    student : antibiotic(3) ::= true &
  student : 'rehydration intravenous'(3) ::= true &
  student : hospitalization(2) ::= true &
    { existing_metafact( student, 'general tests'(_), true ) } &
    { write_param( modified, 3 ) }
==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & specific_tests( stool ),
  visible_symptoms(int, b1) <- not diarrhea(3) & not vomiting(3) &
  irritability(neutral, 3 ),
  specific_tests( stool ) <- blood( absent,3 ) & 'bacterial culture'(positive, 3)
  & parasites( absent, 3 ) & viral( negative, 3 ) ).

% ----- only blood culture test and intravenous
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'specific test'( 'blood culture', 3 ) ::= true &
  student : 'specific test'( stool, 3 ) ::= false &
  student : antibiotic(3) ::= true &
  student : 'rehydration intravenous'(3) ::= true &
  student : hospitalization(2) ::= true &
    { existing_metafact( student, 'general tests'(_), true ) } &
    { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) &
  specific_tests( 'blood culture' ),
  visible_symptoms(int, b1) <- not diarrhea(3) & not vomiting(3) &
  irritability(neutral, 3 ),
  specific_tests( 'blood culture' ) <- 'blood culture'( positive, 3 ) ).

```

```

% ----- all correct specific test, but no intravenous
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'specific test'( 'blood culture', 3 ) ::= true &
  student : antibiotic(3) ::= false &
  student : 'rehydration intravenous'(3) ::= false &
  student : hospitalization(2) ::= true &
    { existing_metafact( student, 'general tests'(_), true ) } &
    { write_param( modified, 3 ) }
==>
modify ( bacteria( int ) <-& specific_tests( stool ) &
  specific_tests( 'blood culture' ),
  specific_tests( stool ) <- blood( absent,3 ) & 'bacterial culture'(positive, 3)
  & parasites( absent, 3 ) & viral( negative, 3 ),
  specific_tests( 'blood culture' ) <- 'blood culture'( positive, 3 ) ).

% ----- only stool test, but no intravenous
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'specific test'( 'blood culture', 3 ) ::= false &
  student : antibiotic(3) ::= false &
  student : 'rehydration intravenous'(3) ::= false &
  student : hospitalization(2) ::= true &
    { existing_metafact( student, 'general tests'(_), true ) } &
    { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& specific_tests( stool ),
  specific_tests( stool ) <- blood( absent,3 ) & 'bacterial culture'(positive, 3)
  & parasites( absent, 3 ) & viral( negative, 3 ) ).

% ----- only blood culture test, but no intravenous
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'specific test'( 'blood culture', 3 ) ::= true &
  student : 'specific test'( stool, 3 ) ::= false &
  student : antibiotic(3) ::= false &
  student : 'rehydration intravenous'(3) ::= false &
  student : hospitalization(2) ::= true &
    { existing_metafact( student, 'general tests'(_), true ) } &
    { write_param( modified, 3 ) }

```

```

==>
modify ( bacteria( int ) <-& specific_tests( 'blood culture' ),
        specific_tests( 'blood culture' ) <- 'blood culture'( positive, 3 ) ).

% ----- only intravenous, none of specific test
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : antibiotic(3) ::= true &
  student : 'rehydration intravenous'(3) ::= true &
  student : 'specific test'( 'blood culture', 3 ) ::= false &
  { \+ existing_metafact( student, 'specific test'( stool, _ ), true ) } &
  student : hospitalization(2) ::= true &
  { existing_metafact( student, 'general tests'(_), true ) } &
  { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
        visible_symptoms(int, b1) <- not diarrhea(3) & not vomiting(3) &
        irritability(neutral, 3 ) ).

%%%%%%%%% [exam & history] [hospitalization]
%%%%%%%%%
%%%%%%%%% [general exam] [patient history & hospitalization] %%%%%%%%%%
% ----- general tests requested
% ----- interim treatment requested, or not
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  { existing_metafact( student, 'general exam'(_), true ) } &
  { existing_metafact( student, 'patient history'(_), true ) } &
  student : 'general tests'(3) ::= true &
  student : hospitalization(2) ::= true &
  { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& blood_test & urine_test,
        blood_test <- 'red cell'( normal, 3 ) & 'white cell'( normal, 3 ) &
        'cell smear'( normal, 3 ),
        urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
        sugar( absent, 3 ) & proteins( absent, 3 ) ).

```

```

% ----- only interim treatment requested, no general tests
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'interim treatment'(3) ::= true &
  student : hospitalization(2) ::= true &
    { \+ existing_metafact( student, 'general tests'(_), true ) } &
    { existing_metafact( student, 'general exam'(_), true ) } &
    { existing_metafact( student, 'patient history'(_), true ) } &
    { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
  visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
  'refusal to eat'(3) & irritability(neutral, 3) ).

%%%%%%%%% [exam] [general tests & history & hospitalization] { W > 10 }
%%%%%%%%%

% ----- only interim treatment requested
% ----- (general tests : pending, general exam and history done)
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  sick_infant : 'general tests'( pending, 2 ) ::= true &
  student : 'interim treatment'( 3 ) ::= true &
  { \+ existing_metafact( student, 'specific test'(_), true ) } &
  { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & blood_test & urine_test,
  visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
  'refusal to eat'(3) & irritability(neutral, 3),
  blood_test <- 'red cell'( normal, 3 ) & 'white cell'( normal, 3 ) &
  'cell smear'( normal, 3 ),
  urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
  sugar( absent, 3 ) & proteins( absent, 3 ) ).

% ----- all specific tests, no treatment
% ----- general tests(pending)
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'specific test'( 'blood culture', 3 ) ::= true &
  sick_infant : 'general tests'( pending, 2 ) ::= true &
  { \+ existing_metafact( student, 'interim treatment'(_), true ) } &
  { write_param( modified, 3 ) }

```

```

==>
modify ( bacteria( int ) <-& blood_test & urine_test
      & specific_tests( stool ) & specific_tests( 'blood culture' ),
      blood_test <- 'red cell'( normal, 3 ) & 'white cell'( normal, 3 ) &
        'cell smear'( normal, 3 ),
      urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
        sugar( absent, 3 ) & proteins( absent, 3 ),
      specific_tests( stool ) <- blood( absent, 3 ) & 'bacterial culture'(positive, 3)
        & parasites( absent, 3 ) & viral( negative, 3 ),
      specific_tests( 'blood culture' ) <- 'blood culture'( positive, 3 ) ).

```

```

% ----- only stool test, no treatment

```

```

% ----- general tests(pending)

```

```

step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'specific test'( 'blood culture', 3 ) ::= false &
  sick_infant : 'general tests'( pending, 2 ) ::= true &
    { \+ existing_metafact( student, 'interim treatment'(_), true ) } &
    { write_param( modified, 3 ) }

```

```

==>

```

```

modify ( bacteria( int ) <-& blood_test & urine_test & specific_tests( stool ),
      blood_test <- 'red cell'( normal, 3 ) & 'white cell'( normal, 3 ) &
        'cell smear'( normal, 3 ),
      urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
        sugar( absent, 3 ) & proteins( absent, 3 ),
      specific_tests( stool ) <- blood( absent, 3 ) & 'bacterial culture'(positive, 3)
        & parasites( absent, 3 ) & viral( negative, 3 ) ).

```

```

% ----- only blood culture test, no treatment

```

```

% ----- general tests(pending)

```

```

step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'specific test'( 'blood culture', 3 ) ::= true &
  student : 'specific test'( stool, 3 ) ::= false &
  sick_infant : 'general tests'( pending, 2 ) ::= true &
    { \+ existing_metafact( student, 'interim treatment'(_), true ) } &
    { write_param( modified, 3 ) }

```



```

==>
modify ( bacteria( int ) <-& blood_test & urine_test &
        specific_tests( 'blood culture' ),
        blood_test <- 'red cell'( normal, 3 ) & 'white cell'( normal, 3 ) &
        'cell smear'( normal, 3 ),
        urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
        sugar( absent, 3 ) & proteins( absent, 3 ),
        specific_tests( 'blood culture' ) <- 'blood culture'( positive, 3 ) ).

% ----- all specific tests and interim treatment requested
% ----- general tests(pending)
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _ ) ::= true & { W > 10 } &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'specific test'( 'blood culture', 3 ) ::= true &
  student : 'interim treatment'(3) ::= true &
  sick_infant : 'general tests'( pending, 2 ) ::= true &
  { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & blood_test & urine_test
        & specific_tests( stool ) & specific_tests( 'blood culture' ),
        visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
        irritability(high, 3),
        blood_test <- 'red cell'( normal, 3 ) & 'white cell'( normal, 3 ) &
        'cell smear'( normal, 3 ),
        urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
        sugar( absent, 3 ) & proteins( absent, 3 ),
        specific_tests( stool ) <- blood( absent, 3 ) & 'bacterial culture'(positive, 3)
        & parasites( absent, 3 ) & viral( negative, 3 ),
        specific_tests( 'blood culture' ) <- 'blood culture'( positive, 3 ) ).

% ----- only stool test and interim treatment requested
% ----- general tests(pending)
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _ ) ::= true & { W > 10 } &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'specific test'( 'blood culture', 3 ) ::= false &
  student : 'interim treatment'(3) ::= true &
  sick_infant : 'general tests'( pending, 2 ) ::= true &
  { write_param( modified, 3 ) }

```

```

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & blood_test & urine_test
      & specific_tests( stool ),
      visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
      irritability(high, 3),
      blood_test <- 'red cell'( normal, 3 ) & 'white cell'( normal, 3 ) &
      'cell smear'( normal, 3 ),
      urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
      sugar( absent, 3 ) & proteins( absent, 3 ),
      specific_tests( stool ) <- blood( absent, 3 ) & 'bacterial culture'(positive, 3)
      & parasites( absent, 3 ) & viral( negative, 3 ) ).

```

```

% ----- only blood culture test and interim treatment requested

```

```

% ----- general tests(pending)

```

```

step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _ ) ::= true & { W > 10 } &
  student : 'specific test'( 'blood culture', 3 ) ::= true &
  student : 'specific test'( stool, 3 ) ::= false &
  student : 'interim treatment'(3) ::= true &
  sick_infant : 'general tests'( pending, 2 ) ::= true &
  { write_param( modified, 3 ) }

```

```

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & blood_test & urine_test
      & specific_tests( 'blood culture' ),
      visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
      irritability(high, 3),
      blood_test <- 'red cell'( normal, 3 ) & 'white cell'( normal, 3 ) &
      'cell smear'( normal, 3 ),
      urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
      sugar( absent, 3 ) & proteins( absent, 3 ),
      specific_tests( 'blood culture' ) <- 'blood culture'( positive, 3 ) ).

```

```

%%%%%%%%% [general exam] [hospitalization] %%%%%%%%%%

```

```

% ----- patient history selected, tests - not

```

```

step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _ ) ::= true & { W > 10 } &
  student : 'general tests'(3) ::= false &
  student : 'patient history'(3) ::= true &
  student : hospitalization(2) ::= true &
  { write_param( modified, 3 ) }

```

```

==>
modify ( bacteria( int ) <-& patient_history,
      patient_history <- diet( 'no change' ) & family( 'no similar symptoms' ) &
      'bowel movement'( normal ) & 'no previous treatment' &
      'no abdominal obstruction' ).

```

```

% ----- history and tests requested (exam - earlier)
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'patient history'(3) ::= true &
    student : 'general tests'(3) ::= true &
    student : hospitalization(2) ::= true &
    { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& patient_history & 'general tests'( pending, 3 ),
  patient_history <- diet( 'no change' ) & family( 'no similar symptoms' ) &
    'bowel movement'( normal ) & 'no previous treatment' &
    'no abdominal obstruction' ) .

%%%%%%%%%      [patient history]      [exam & general tests]      %%%%%%%%%%
%%%%%%%%%      [general exam]        [history & general tests]    %%%%%%%%%%
%%%%%%%%%      Pending on general tests before      !!%%%%%%%%%
% ----- hospitalization and both specific tests requested
% ----- interim treatment requested or not
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  { existing_metafact( sick_infant, 'general tests'( pending, 2 ), true ) } &
  student : hospitalization(3) ::= true &
    student : 'specific test'( 'blood culture', 3 ) ::= true &
    student : 'specific test'( stool, 3 ) ::= true &
    { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & blood_test & urine_test
  & specific_tests( stool ) & specific_tests( 'blood culture' ),
  visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
    'refusal to eat'(3) & irritability(neutral, 3),
    blood_test <- 'red cell'( normal, 3 ) & 'white cell'( normal, 3 ) &
    'cell smear'( normal, 3 ),
    urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
    sugar( absent, 3 ) & proteins( absent, 3 ),
    specific_tests( stool ) <- blood( absent, 3 ) & 'bacterial culture'(positive, 3)
    & parasites( absent, 3 ) & viral( negative, 3 ),
    specific_tests( 'blood culture' ) <- 'blood culture'( positive, 3 ) ).

```

```

% ----- hospitalization and only stool test requested
% ----- interim treatment requested or not
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  { existing_metafact( sick_infant, 'general tests'( pending, 2 ), true ) } &
  student : hospitalization(3) ::= true &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'specific test'( 'blood culture', 3 ) ::= false &
  { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & blood_test & urine_test
  & specific_tests( stool ),
  visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
  'refusal to eat'(3) & irritability(neutral, 3),
  blood_test <- 'red cell'( normal, 3 ) & 'white cell'( normal, 3 ) &
  'cell smear'( normal, 3 ),
  urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
  sugar( absent, 3 ) & proteins( absent, 3 ),
  specific_tests( stool ) <- blood( absent, 3 ) & 'bacterial culture'(positive, 3)
  & parasites( absent, 3 ) & viral( negative, 3 ) ).

% ----- hospitalization and only blood culture test requested
% ----- interim treatment requested or not
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  { existing_metafact( sick_infant, 'general tests'( pending, 2 ), true ) } &
  student : hospitalization(3) ::= true &
  student : 'specific test'( 'blood culture', 3 ) ::= true &
  student : 'specific test'( stool, 3 ) ::= false &
  { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & blood_test & urine_test
  & specific_tests( 'blood culture' ),
  visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
  'refusal to eat'(3) & irritability(neutral, 3),
  blood_test <- 'red cell'( normal, 3 ) & 'white cell'( normal, 3 ) &
  'cell smear'( normal, 3 ),
  urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
  sugar( absent, 3 ) & proteins( absent, 3 ),
  specific_tests( 'blood culture' ) <- 'blood culture'( positive, 3 ) ).

```

```

% ----- hospitalization and interim treatment requested
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  { existing_metafact( sick_infant, 'general tests'( pending, 2 ), true ) } &
  student : hospitalization(3) ::= true &
  student : 'interim treatment'(3) ::= true &
    { \+ existing_metafact( student, 'specific test'(_, _), true ) } &
    { write_param( modified, 3 ) }
==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & blood_test & urine_test,
  visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
  irritability(high, 3),
  blood_test <- 'red cell'( normal, 3 ) & 'white cell'( normal, 3 ) &
    'cell smear'( normal, 3 ),
  urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
    sugar( absent, 3 ) & proteins( absent, 3 ) ).

% ----- hospitalization requested only
% ----- no specific test and interim treatment
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  { existing_metafact( sick_infant, 'general tests'( pending, 2 ), true ) } &
  student : hospitalization(3) ::= true &
  student : 'interim treatment'(3) ::= false &
    { \+ existing_metafact( student, 'specific test'(_, _), true ) } &
    { write_param( modified, 3 ) }
==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & blood_test & urine_test,
  visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
  'refusal to eat'(3) & irritability(neutral, 3),
  blood_test <- 'red cell'( normal, 3 ) & 'white cell'( normal, 3 ) &
    'cell smear'( normal, 3 ),
  urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
    sugar( absent, 3 ) & proteins( absent, 3 ) ).

%%%%%%%%% [general exam] [patient history] %%%%%%%%%%
%%%%%%%%% [patient history] [general exam] %%%%%%%%%%
% ----- hospitalization and general tests requested
% ----- interim treatment or not
step(3) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : hospitalization(3) ::= true &
  student : 'general tests'(3) ::= true &
    { write_param( modified, 3 ) }

```

```

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & blood_test & urine_test,
        visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
        'refusal to eat'(3) & irritability(neutral, 3),
        blood_test <- 'red cell'( normal, 3 ) & 'white cell'( normal, 3 ) &
        'cell smear'( normal, 3 ),
        urine_test <- ketones( elevated, 3 ) & 'blood in urine'( absent, 3 ) &
        sugar( absent, 3 ) & proteins( absent, 3 ) ) .

% ----- hospitalization and interim treatment requested
% ----- no general tests
step(3) ::= true &
    sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
    student : hospitalization(3) ::= true &
    student : 'interim treatment'(3) ::= true &
    student : 'general tests'(3) ::= false &
    { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
        visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
        'refusal to eat'(3) & irritability(neutral, 3) ) .

% ----- hospitalization requested only
% ----- no general tests and interim treatment
step(3) ::= true &
    sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
    student : hospitalization(3) ::= true &
    student : 'interim treatment'(3) ::= false &
    student : 'general tests'(3) ::= false &
    { write_param( modified, 3 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
        visible_symptoms(int, b1) <- diarrhea(3) & vomiting(3) &
        'refusal to eat'(3) & irritability(neutral, 3) ) .

%----- Selections 4
%%%%%%%% { W =< 10} %%%

%%%%%%%% [exam & history] [interim treatment & general tests] %%%
% rehydration oral and specific test requested,
{ read_param( modified, 3 ) } &
    sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W =< 10 } &
    student : 'rehydration oral'(3) ::= true &
    student : 'specific test'( stool, 3 ) ::= true

```

```

==>
select ('virus of intestinal tract'(4), 'bacterial infection of intestinal tract'(4),
       'virus of neurological tract'(4) ) &
       step(3) ::= false & step(4) ::= true .

% only stool test requested, no rehydration oral
{ read_param( modified, 3 ) } &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W =< 10 } &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'rehydration oral'( 3 ) ::= false &
  { \+ existing_metafact( student, hospitalization(_), true ) } &
  { existing_metafact( student, 'patient history'(_), true ) } &
  { existing_metafact( student, 'general exam'(_), true ) }

==>
select ( 'rehydration oral'(4), antibiotic(4), 'rehydration intravenous'(4),
       'contact specialist'(4), hospitalization(4),
       'specific test'('csf exam', 4 ), 'specific test'( 'blood culture', 4 ) ) &
       step(3) ::= false & step(4) ::= true .

% only rehydration oral requested, no specific test
{ read_param( modified, 3 ) } &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W =< 10 } &
  student : 'rehydration oral'(3) ::= true &
  student : 'specific test'( stool, 3 ) ::= false &
  { existing_metafact( student, 'general tests'(_), true ) }

==>
select ( antibiotic(4), 'rehydration intravenous'(4), 'contact specialist'(4),
       hospitalization(4), 'specific test'('csf exam', 4 ),
       'specific test'( 'blood culture', 4 ),
       'specific test'( stool, 4 ) ) &
       step(3) ::= false & step(4) ::= true .

%%%%%%%% [general exam & patient history] [interim treatment] %%%%%%%%%
% only general tests requested
{ read_param( modified, 3 ) } &
  student : 'general tests'(3) ::= true &
  student : 'interim treatment'(2) ::= true &
  { \+ existing_metafact( student, hospitalization(_), true ) }

==>
select ( 'specific test'( stool, 4 ), 'specific test'('csf exam', 4 ),
       'specific test'( 'blood culture', 4 ), hospitalization(4),
       'rehydration oral'(4), antibiotic(4), 'rehydration intravenous'(4) ) &
       step(3) ::= false & step(4) ::= true .

```

```

% % % % %      [exam & history]      [general tests] {W =< 10}      % % % % %
% % % % %      [general exam]      [history & general tests]      {W =< 10}
% % % % %
% % % % %      [patient history]      [exam & general tests]      {W =< 10}
% % % % %

% specific test and interim treatment requested
{ read_param( modified, 3 ) } &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'interim treatment'(3) ::= true &
  student : 'general tests'(2) ::= true &
    { \+ existing_metafact( student, hospitalization( ), true ) } &
    { existing_metafact( student, 'patient history'( ), true ) } &
    { existing_metafact( student, 'general exam'( ), true ) }

== .
select ( 'rehydration oral'(4), antibiotic(4), 'rehydration intravenous'(4),
  'contact specialist'(4), hospitalization(4),
  'specific test'( 'blood culture', 4 ) ) &
  step(3) ::= false & step(4) ::= true .

% interim treatment requested, no specific test
{ read_param( modified, 3 ) } &
  student : 'interim treatment'(3) ::= true &
  student : 'general tests'(2) ::= true &
    { \+ existing_metafact( student, hospitalization( ), true ) } &
    { \+ existing_metafact( student, 'specific test'( stool, _ ), true ) }

==>
select ( 'specific test'( stool, 4 ), hospitalization(4),
  'specific test'( 'blood culture', 4 ), 'rehydration oral'(4),
  antibiotic(4), 'rehydration intravenous'(4) ) &
  step(3) ::= false & step(4) ::= true .

% only stool test requested, no interim treatment
{ read_param( modified, 3 ) } &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'general tests'(2) ::= true &
    { existing_metafact( student, 'patient history'( ), true ) } &
    { existing_metafact( student, 'general exam'( ), true ) } &
    { \+ existing_metafact( student, hospitalization( ), true ) } &
    { \+ existing_metafact( student, 'interim treatment'( ), true ) }

==>
select ( 'interim treatment'(4), 'contact specialist'(4), hospitalization(4),
  'specific test'( 'csf exam', 4 ), 'specific test'( 'blood culture', 4 ) ) &
  step(3) ::= false & step(4) ::= true .

```



```

%%%%%%%% [general exam] [patient history] {W =< 10} %%%%%%%%%
%%%%%%%% [patient history] [general exam] {W =< 10} %%%%%%%%%
% general tests and interim treatment requested
{ read_param( modified, 3 ) } &
  student : 'general tests'(3) ::= true &
  student : 'interim treatment'(3) ::= true &
    { \+ existing_metafact( student, hospitalization( ), true ) } &
    { existing_metafact( student, 'patient history'( ), true ) } &
    { existing_metafact( student, 'general exam'( ), true ) }
==>
select ( 'rehydration oral'(4), antibiotic(4), 'rehydration intravenous'(4),
  'contact specialist'(4), hospitalization(4), 'specific test'( stool, 4 ),
  'specific test'( 'csf exam', 4 ), 'specific test'( 'blood culture', 4 ) ) &
  step(3) ::= false & step(4) ::= true .

% general tests requested, no interim treatment
{ read_param( modified, 3 ) } &
  student : 'general tests'(3) ::= true &
    { \+ existing_metafact( student, hospitalization( ), true ) } &
    { existing_metafact( student, 'patient history'( ), true ) } &
    { existing_metafact( student, 'general exam'( ), true ) } &
    { \+ existing_metafact( student, 'interim treatment'( ), true ) }
==>
select ( 'interim treatment'(4), 'contact specialist'(4), hospitalization(4),
  'specific test'( stool, 4 ), 'specific test'( 'csf exam', 4 ),
  'specific test'( 'blood culture', 4 ) ) &
  step(3) ::= false & step(4) ::= true .

% interim treatment requested, no general tests
{ read_param( modified, 3 ) } &
  student : 'interim treatment'(3) ::= true &
  student : 'general tests'(3) ::= false &
    { \+ existing_metafact( student, hospitalization( ), true ) } &
    { existing_metafact( student, 'patient history'( ), true ) } &
    { existing_metafact( student, 'general exam'( ), true ) }
==>
select ( 'general tests'(4), 'contact specialist'(4), hospitalization(4),
  'rehydration oral'(4), antibiotic(4), 'rehydration intravenous'(4) ) &
  step(3) ::= false & step(4) ::= true .

```

```

% % % % %      { W > 10 }      % % % % %
% % % % %      [exam & history]      [general tests & interim treatment]      % % % % %
% antibiotic, rehydration intravenous, hospitalization
% and both specific tests requested.
{ read_param( modified, 3 ) } &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'rehydration intravenous'(3) ::= true &
  student : antibiotic(3) ::= true &
  student : 'hospitalization'(3) ::= true &
  student : 'specific test'( stool, 3 ) ::= true &
    student : 'specific test'( 'blood culture', 3 ) ::= true &
    { existing_metafact( student, 'general tests'(_), true ) }
==>
select ('virus of intestinal tract'(4), 'bacterial infection of intestinal tract'(4),
  'virus of neurological tract'(4) ) &
  step(3) ::= false & step(4) ::= true .

% rehydration intravenous, antibiotic, hospitalization
% and only stool test requested.
{ read_param( modified, 3 ) } &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : antibiotic(3) ::= true &
  student : 'rehydration intravenous'(3) ::= true &
  student : 'hospitalization'(3) ::= true &
  student : 'specific test'( stool, 3 ) ::= true &
    student : 'specific test'( 'blood culture', 3 ) ::= false &
    { existing_metafact( student, 'general tests'(_), true ) }
==>
select ( 'rehydration oral'(4), 'contact specialist'(4),
  'specific test'( 'csf exam', 4 ), 'specific test'( 'blood culture', 4 ) ) &
  step(3) ::= false & step(4) ::= true .

% antibiotic, rehydration intravenous, hospitalization
% and only blood culture test requested.
{ read_param( modified, 3 ) } &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : antibiotic(3) ::= true &
  student : 'rehydration intravenous'(3) ::= true &
  student : 'hospitalization'(3) ::= true &
    student : 'specific test'( 'blood culture', 3 ) ::= true &
  student : 'specific test'( stool, 3 ) ::= false &
    { existing_metafact( student, 'general tests'(_), true ) }

```

```

==>
select ( 'rehydration oral'(4), 'contact specialist'(4), 'specific test'( stool, 4 ),
        'specific test'('csf exam', 4 ) ) &
        step(3) ::= false & step(4) ::= true .

% both specific tests requested and hospitalization
% no rehydration intravenous and antibiotic
{ read_param( modified, 3 ) } &
  sick_infant : 'loss of weight'(W, 'per cent', _ ) ::= true & { W > 10 } &
  student : 'specific test'( 'blood culture',3 ) ::= true &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'hospitalization'(3) ::= true &
  student : 'rehydration intravenous'(3) ::= false &
  student : antibiotic(3) ::= false &
  { existing_metafact( student, 'patient history'(_), true ) } &
  { existing_metafact( student, 'general exam'(_), true ) }

==>
select ( 'rehydration oral'(4), antibiotic(4), 'rehydration intravenous'(4),
        'contact specialist'(4), 'specific test'('csf exam', 4 ) ) &
        step(3) ::= false & step(4) ::= true .

% only stool test requested and hospitalization
% no rehydration intravenous, antibiotic, and blood culture test
{ read_param( modified, 3 ) } &
  sick_infant : 'loss of weight'(W, 'per cent', _ ) ::= true & { W > 10 } &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'specific test'( 'blood culture',3 ) ::= false &
  student : 'hospitalization'(3) ::= true &
  student : antibiotic(3) ::= false &
  student : 'rehydration intravenous'(3) ::= false &
  { existing_metafact( student, 'patient history'(_), true ) } &
  { existing_metafact( student, 'general exam'(_), true ) }

==>
select ( 'rehydration oral'(4), antibiotic(4), 'rehydration intravenous'(4),
        'contact specialist'(4), 'specific test'('csf exam', 4 ),
        'specific test'( 'blood culture', 4 ) ) &
        step(3) ::= false & step(4) ::= true .

```

```

% only blood culture test requested and hospitalization
% no rehydration intravenous, antibiotic, and stool
{ read_param( modified, 3 ) } &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'specific test'( 'blood culture', 3 ) ::= true &
  student : 'specific test'( stool, 3 ) ::= false &
  student : 'hospitalization'(3) ::= true &
  student : 'rehydration intravenous'(3) ::= false &
  student : antibiotic(3) ::= false &
    { existing_metafact( student, 'patient history'(_), true ) } &
    { existing_metafact( student, 'general exam'(_), true ) }
==>
select ( 'rehydration oral'(4), antibiotic(4), 'rehydration intravenous'(4),
  'contact specialist'(4), 'specific test'( stool, 4 ),
  'specific test'('csf exam', 4 ) ) &
  step(3) ::= false & step(4) ::= true .

% antibiotic, rehydration intravenous and hospitalization requested
% none of specific tests
{ read_param( modified, 3 ) } &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : antibiotic(3) ::= true &
  student : 'rehydration intravenous'(3) ::= true &
  student : 'hospitalization'(3) ::= true &
  student : 'specific test'( 'blood culture', 3 ) ::= false &
  student : 'specific test'( stool, 3 ) ::= false &
    { existing_metafact( student, 'patient history'(_), true ) } &
    { existing_metafact( student, 'general exam'(_), true ) }
==>
select ( 'rehydration oral'(4), 'contact specialist'(4),
  'specific test'('csf exam', 4 ), 'specific test'( 'blood culture', 4 ),
  'specific test'( stool, 4 ) ) &
  step(3) ::= false & step(4) ::= true .

% only hospitalization requested
% no rehydration intravenous, antibiotic, none of specific tests
{ read_param( modified, 3 ) } &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'hospitalization'(3) ::= true &
  student : antibiotic(3) ::= false &
  student : 'rehydration intravenous'(3) ::= false &
  student : 'specific test'( 'blood culture', 3 ) ::= false &
  student : 'specific test'( stool, 3 ) ::= false &
    { existing_metafact( student, 'patient history'(_), true ) } &
    { existing_metafact( student, 'general exam'(_), true ) }

```

```

==>
select ( 'rehydration intravenous'(4), antibiotic(4), 'rehydration oral'(4),
        'contact specialist'(4), 'specific test'( 'csf exam', 4 ),
        'specific test'( 'blood culture', 4 ), 'specific test'( stool, 4 ) ) &
        step(3) ::= false & step(4) ::= true .

%%%%%%%% [exam & history] [interim treatment] %%%%%%%%%
% general tests requested and hospitalization
{ read_param( modified, 3 ) } &
    student : 'hospitalization'(3) ::= true &
    student : 'general tests'(3) ::= true &
    student : 'general exam'(1) ::= true &
    student : 'patient history'(1) ::= true &
    student : 'interim treatment'(2) ::= true
==>
select ( 'specific test'( stool, 4 ), 'specific test'( 'csf exam', 4 ),
        'specific test'( 'blood culture', 4 ), 'rehydration oral'(4), antibiotic(4),
        'rehydration intravenous'(4), 'contact specialist'(4) ) &
        step(3) ::= false & step(4) ::= true .

% only hospitalization requested, no general tests
{ read_param( modified, 3 ) } &
    student : 'hospitalization'(3) ::= true &
    student : 'general tests'(3) ::= false &
    student : 'general exam'(1) ::= true &
    student : 'patient history'(1) ::= true &
    student : 'interim treatment'(2) ::= true

==>
select ( 'general tests'(4), 'rehydration oral'(4), antibiotic(4),
        'rehydration intravenous'(4), 'contact specialist'(4) ) &
        step(3) ::= false & step(4) ::= true .

%%%%%%%% [exam & history] [hospitalization] %%%%%%%%%
%%%%%%%% [exam] [patient history & hospitalization] %%%%%%%%%
% general tests and interim treatment requested
{ read_param( modified, 3 ) } &
    student : 'general tests'(3) ::= true &
    student : 'interim treatment'(3) ::= true &
    student : hospitalization(2) ::= true &
        { existing_metafact( student, 'patient history'(T), true ) } &
        { T < 3 } &
        { existing_metafact( student, 'general exam'(_), true ) }

```

```

==>
select ( 'rehydration oral'(4), antibiotic(4), 'rehydration intravenous'(4),
        'contact specialist'(4), 'specific test'( stool, 4 ),
        'specific test'( 'csf exam', 4 ), 'specific test'( 'blood culture', 4 ) ) &
        step(3) ::= false & step(4) ::= true .

% general tests requested, no interim treatment
{ read_param( modified, 3 ) } &
  student : 'general tests'(3) ::= true &
  student : hospitalization(2) ::= true &
    { existing_metafact( student, 'patient history'(T), true ) } &
    { T < 3 } &
    { existing_metafact( student, 'general exam'(_), true ) } &
    { \+ existing_metafact( student, 'interim treatment'(_), true ) }

==>
select ( 'interim treatment'(4), 'contact specialist'(4),
        'specific test'( stool, 4 ), 'specific test'( 'csf exam', 4 ),
        'specific test'( 'blood culture', 4 ) ) &
        step(3) ::= false & step(4) ::= true .

% interim treatment requested, no general tests
{ read_param( modified, 3 ) } &
  student : 'interim treatment'(3) ::= true &
  student : hospitalization(2) ::= true &
    { existing_metafact( student, 'patient history'(T), true ) } &
    { T < 3 } &
    { existing_metafact( student, 'general exam'(_), true ) } &
    { \+ existing_metafact( student, 'general tests'(_), true ) }

==>
select ( 'general tests'(4), 'contact specialist'(4),
        'rehydration oral'(4), antibiotic(4), 'rehydration intravenous'(4) ) &
        step(3) ::= false & step(4) ::= true .

%%%%%%%%%      [exam & history]      [hospitalization & general tests]      %%%%%%%%%%
%%%%%%%%%      [exam]      [patient history & hospitalization & general tests] %%%%%%%%%%
% all specific tests and interim treatment requested
{ read_param( modified, 3 ) } &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'specific test'( 'blood culture', 3 ) ::= true &
  student : 'interim treatment'(3) ::= true &
  student : 'general tests'(2) ::= true &
  student : hospitalization(2) ::= true &
    { existing_metafact( student, 'patient history'(_), true ) } &
    { existing_metafact( student, 'general exam'(_), true ) }

```

==>

```
select ( 'rehydration oral'(4), antibiotic(4), 'rehydration intravenous'(4),
        'contact specialist'(4), 'specific test'( 'csf exam', 4 ) ) &
        step(3) ::= false & step(4) ::= true .
```

% only stool test and interim treatment requested

```
{ read_param( modified, 3 ) } &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'specific test'( 'blood culture', 3 ) ::= false &
  student : 'interim treatment'(3) ::= true &
  student : 'general tests'(2) ::= true &
  student : hospitalization(2) ::= true &
  { existing_metafact( student, 'patient history'(_), true ) } &
  { existing_metafact( student, 'general exam'(_), true ) }
```

==>

```
select ( 'rehydration oral'(4), antibiotic(4), 'rehydration intravenous'(4),
        'contact specialist'(4), 'specific test'( 'csf exam', 4 ),
        'specific test'( 'blood culture', 4 ) ) &
        step(3) ::= false & step(4) ::= true .
```

% only blood culture test and interim treatment requested

```
{ read_param( modified, 3 ) } &
  student : 'specific test'( 'blood culture', 3 ) ::= true &
  student : 'specific test'( stool, 3 ) ::= false &
  student : 'interim treatment'(3) ::= true &
  student : 'general tests'(2) ::= true &
  student : hospitalization(2) ::= true &
  { existing_metafact( student, 'patient history'(_), true ) } &
  { existing_metafact( student, 'general exam'(_), true ) }
```

==>

```
select ( 'rehydration oral'(4), antibiotic(4), 'rehydration intravenous'(4),
        'contact specialist'(4), 'specific test'( stool, 4 ),
        'specific test'( 'csf exam', 4 ) ) &
        step(3) ::= false & step(4) ::= true .
```

% interim treatment requested, no specific tests

```
{ read_param( modified, 3 ) } &
  student : 'interim treatment'(3) ::= true &
  student : 'general tests'(2) ::= true &
  student : hospitalization(2) ::= true &
  { existing_metafact( student, 'patient history'(_), true ) } &
  { existing_metafact( student, 'general exam'(_), true ) } &
  { \+ existing_metafact( student, 'specific test'( stool, _ ), true ) } &
  { \+ existing_metafact( student, 'specific test'( 'blood culture', _ ), true ) }
```

```

==>
select ( 'specific test'( stool, 4 ), 'specific test'( 'csf exam', 4 ),
        'specific test'( 'blood culture', 4 ), 'rehydration oral'(4), antibiotic(4),
        'rehydration intravenous'(4) ) &
        step(3) ::= false & step(4) ::= true .

```

```

% all specific tests requested, no interim treatment
{ read_param( modified, 3 ) } &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'specific test'( 'blood culture', 3 ) ::= true &
  student : 'general tests'(2) ::= true &
  student : hospitalization(2) ::= true &
    { existing_metafact( student, 'patient history'(_), true ) } &
    { existing_metafact( student, 'general exam'(_), true ) } &
    { \+ existing_metafact( student, 'interim treatment'(_), true ) }

```

```

==>
select ( 'interim treatment'(4), 'contact specialist'(4),
        'specific test'( 'csf exam', 4 ) ) &
        step(3) ::= false & step(4) ::= true .

```

```

% only stool test requested, no interim treatment
{ read_param( modified, 3 ) } &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'specific test'( 'blood culture', 3 ) ::= false &
  student : 'general tests'(2) ::= true &
  student : hospitalization(2) ::= true &
    { existing_metafact( student, 'patient history'(_), true ) } &
    { existing_metafact( student, 'general exam'(_), true ) } &
    { \+ existing_metafact( student, 'interim treatment'(_), true ) }

```

```

==>
select ( 'interim treatment'(4), 'contact specialist'(4),
        'specific test'( 'csf exam', 4 ), 'specific test'( 'blood culture', 4 ) ) &
        step(3) ::= false & step(4) ::= true .

```

```

% only blood culture test requested, no interim treatment
{ read_param( modified, 3 ) } &
  student : 'specific test'( 'blood culture', 3 ) ::= true &
  student : 'specific test'( stool, 3 ) ::= false &
  student : 'general tests'(2) ::= true &
  student : hospitalization(2) ::= true &
    { existing_metafact( student, 'patient history'(_), true ) } &
    { existing_metafact( student, 'general exam'(_), true ) } &
    { \+ existing_metafact( student, 'interim treatment'(_), true ) }

```



```

==>
select ( 'interim treatment'(4), 'contact specialist'(4),
        'specific test'( stool, 4 ), 'specific test'('csf exam', 4 ) ) &
        step(3) ::= false & step(4) ::= true .

%%%%%%%% [exam & history] [hospitalization & interim treatment] %%%%%%%%%
% only general tests requested
{ read_param( modified, 3 ) } &
  student : 'general tests'(3) ::= true &
  student : 'interim treatment'(2) ::= true &
  student : hospitalization(2) ::= true
==>
select ( 'specific test'( stool, 4 ), 'specific test'('csf exam', 4 ),
        'specific test'( 'blood culture', 4 ), 'rehydration oral'(4),
        antibiotic(4), 'rehydration intravenous'(4) ) &
        step(3) ::= false & step(4) ::= true .

%%%%%%%% [exam & history] [hosp. & interim treatment & general tests]
%%%%%%%%
% antibiotic, rehydration intravenous and both specific tests requested,
{ read_param( modified, 3 ) } &
  sick_infant : 'loss of weight'(W, 'per cent', _ ) ::= true & { W > 10 } &
  student : antibiotic(3) ::= true &
  student : 'rehydration intravenous'(3) ::= true &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'specific test'( 'blood culture', 3 ) ::= true &
  student : 'hospitalization'(2) ::= true &
  { existing_metafact( student, 'general tests'(_), true ) }

==>
select ('virus of intestinal tract'(4), 'bacterial infection of intestinal tract'(4),
        'virus of neurological tract'(4) ) &
        step(3) ::= false & step(4) ::= true .

% antibiotic, rehydration intravenous and only stool test requested,
{ read_param( modified, 3 ) } &
  sick_infant : 'loss of weight'(W, 'per cent', _ ) ::= true & { W > 10 } &
  student : antibiotic(3) ::= true &
  student : 'rehydration intravenous'(3) ::= true &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'specific test'( 'blood culture', 3 ) ::= false &
  student : 'hospitalization'(2) ::= true &
  { existing_metafact( student, 'general tests'(_), true ) }

```

```

==>
select ( 'rehydration oral'(4), 'contact specialist'(4),
        'specific test'('csf exam', 4 ), 'specific test'( 'blood culture', 4 ) ) &
        step(3) ::= false & step(4) ::= true .

% antibiotic, rehydration intravenous and only blood culture test requested,
{ read_param( modified, 3 ) } &
  sick_infant : 'loss of weight'(W, 'per cent', _ ) ::= true & { W > 10 } &
  student : antibiotic(3) ::= true &
  student : 'rehydration intravenous'(3) ::= true &
  student : 'specific test'( 'blood culture',3 ) ::= true &
  student : 'specific test'( stool, 3 )
  student : 'hospitalization'(2) ::= true & ::= false &
    { existing_metafact( student, 'general tests'(_), true ) }
==>
select ( 'rehydration oral'(4), 'contact specialist'(4), 'specific test'( stool, 4 ),
        'specific test'('csf exam', 4 ) ) &
        step(3) ::= false & step(4) ::= true .

% both specific tests requested, no rehydration intravenous, antibiotic
{ read_param( modified, 3 ) } &
  sick_infant : 'loss of weight'(W, 'per cent', _ ) ::= true & { W > 10 } &
  student : 'specific test'( 'blood culture',3 ) ::= true &
  student : 'specific test'( stool, 3 ) ::= true &
  student : antibiotic(3) ::= false &
  student : 'rehydration intravenous'(3) ::= false &
  student : 'hospitalization'(2) ::= true &
    { existing_metafact( student, 'patient history'(_), true ) } &
    { existing_metafact( student, 'general exam'(_), true ) }
==>
select ( 'rehydration oral'(4), antibiotic(4), 'rehydration intravenous'(4),
        'contact specialist'(4), 'specific test'('csf exam', 4 ) ) &
        step(3) ::= false & step(4) ::= true .

% only stool test requested, no rehydration intravenous, antibiotic
{ read_param( modified, 3 ) } &
  sick_infant : 'loss of weight'(W, 'per cent', _ ) ::= true & { W > 10 } &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'specific test'( 'blood culture',3 ) ::= false &
  student : antibiotic(3) ::= false &
  student : 'rehydration intravenous'(3) ::= false &
  student : 'hospitalization'(2) ::= true &
    { existing_metafact( student, 'patient history'(_), true ) } &
    { existing_metafact( student, 'general exam'(_), true ) }

```

```

==>
select ( 'rehydration oral'(4), antibiotic(4), 'rehydration intravenous'(4),
        'contact specialist'(4), 'specific test'('csf exam', 4 ),
        'specific test'('blood culture', 4 ) ) &
step(3) ::= false & step(4) ::= true .

% only blood culture test requested, no rehydration intravenous, antibiotic
{ read_param( modified, 3 ) } &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'specific test'('blood culture',3 ) ::= true &
  student : 'specific test'( stool, 3 ) ::= false &
  student : antibiotic(3) ::= false &
  student : 'rehydration intravenous'(3) ::= false &
  student : 'hospitalization'(2) ::= true &
    { existing_metafact( student, 'patient history'(_), true ) } &
    { existing_metafact( student, 'general exam'(_), true ) }

==>
select ( 'rehydration oral'(4), antibiotic(4), 'rehydration intravenous'(4),
        'contact specialist'(4), 'specific test'( stool, 4 ),
        'specific test'('csf exam', 4 ) ) &
step(3) ::= false & step(4) ::= true .

% only rehydration intravenous and antibiotic requested, none of specific tests
{ read_param( modified, 3 ) } &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : antibiotic(3) ::= true &
  student : 'rehydration intravenous'(3) ::= true &
  student : 'specific test'('blood culture',3 ) ::= false &
  student : 'specific test'( stool, 3 ) ::= false &
  student : 'hospitalization'(2) ::= true &
    { existing_metafact( student, 'patient history'(_), true ) } &
    { existing_metafact( student, 'general exam'(_), true ) }

==>
select ( 'rehydration oral'(4), 'contact specialist'(4),
        'specific test'('csf exam', 4 ), 'specific test'('blood culture', 4 ),
        'specific test'( stool, 4 ) ) &
step(3) ::= false & step(4) ::= true .

```

```

%%%%%% [exam & history] [general tests] %%%%%
%%%%%% [exam] [patient history & general tests] %%%%%
%%%%%% [history] [general exam & general tests] %%%%%
% hospitalization, all specific tests and interim treatment requested
{ read_param( modified, 3 ) } &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'specific test'( 'blood culture', 3 ) ::= true &
  student : 'interim treatment'(3) ::= true &
  student : hospitalization(3) ::= true &
    { existing_metafact( student, 'general tests'(), true ) } &
    { existing_metafact( student, 'patient history'(), true ) } &
    { existing_metafact( student, 'general exam'(), true ) }

==>
select ( 'rehydration oral'(4), antibiotic(4), 'rehydration intravenous'(4),
  'contact specialist'(4), 'specific test'('csf exam', 4 ) ) &
  step(3) ::= false & step(4) ::= true .

% only stool test, hospitalization and interim treatment requested
{ read_param( modified, 3 ) } &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'specific test'( 'blood culture', 3 ) ::= false &
  student : 'interim treatment'(3) ::= true &
  student : hospitalization(3) ::= true &
    { existing_metafact( student, 'general tests'(), true ) } &
    { existing_metafact( student, 'patient history'(), true ) } &
    { existing_metafact( student, 'general exam'(), true ) }

==>
select ( 'rehydration oral'(4), antibiotic(4), 'rehydration intravenous'(4),
  'contact specialist'(4), 'specific test'('csf exam', 4 ),
  'specific test'( 'blood culture', 4 ) ) &
  step(3) ::= false & step(4) ::= true .

% only blood culture test, hospitalization and interim treatment requested
{ read_param( modified, 3 ) } &
  student : 'specific test'( 'blood culture', 3 ) ::= true &
  student : 'specific test'( stool, 3 ) ::= false &
  student : 'interim treatment'(3) ::= true &
  student : hospitalization(3) ::= true &
    { existing_metafact( student, 'general tests'(), true ) } &
    { existing_metafact( student, 'patient history'(), true ) } &
    { existing_metafact( student, 'general exam'(), true ) }

```

```

==>
select ( 'rehydration oral'(4), antibiotic(4), 'rehydration intravenous'(4),
        'contact specialist'(4), 'specific test'( stool, 4 ),
        'specific test'( 'csf exam', 4 ) ) &
        step(3) ::= false & step(4) ::= true .

% hospitalization and interim treatment requested, no specific tests
{ read_param( modified, 3 ) } &
  student : 'interim treatment'(3) ::= true &
  student : hospitalization(3) ::= true &
    { existing_metafact( student, 'general tests'(_), true ) } &
    { \+ existing_metafact( student, 'specific test'( stool, _ ), true ) } &
    { \+ existing_metafact( student, 'specific test'( 'blood culture', _ ), true ) }

==>
select ( 'specific test'( stool, 4 ), 'specific test'( 'csf exam', 4 ),
        'specific test'( 'blood culture', 4 ), 'rehydration oral'(4),
        antibiotic(4), 'rehydration intravenous'(4), 'contact specialist'(4) ) &
        step(3) ::= false & step(4) ::= true .

% hospitalization and all specific tests requested, no interim treatment
{ read_param( modified, 3 ) } &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'specific test'( 'blood culture', 3 ) ::= true &
  student : hospitalization(3) ::= true &
    { existing_metafact( student, 'patient history'(_), true ) } &
    { existing_metafact( student, 'general exam'(_), true ) } &
    { existing_metafact( student, 'general tests'(_), true ) } &
    { \+ existing_metafact( student, 'interim treatment'(_), true ) }

==>
select ( 'interim treatment'(4), 'contact specialist'(4),
        'specific test'( 'csf exam', 4 ) ) &
        step(3) ::= false & step(4) ::= true .

% only stool test and hospitalization requested, no interim treatment
{ read_param( modified, 3 ) } &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'specific test'( 'blood culture', 3 ) ::= false &
  student : hospitalization(3) ::= true &
    { existing_metafact( student, 'patient history'(_), true ) } &
    { existing_metafact( student, 'general exam'(_), true ) } &
    { existing_metafact( student, 'general tests'(_), true ) } &
    { \+ existing_metafact( student, 'interim treatment'(_), true ) }

```

```

==>
select ( 'interim treatment'(4), 'contact specialist'(4),
        'specific test'('csf exam', 4 ), 'specific test'( 'blood culture', 4 ) ) &
        step(3) ::= false & step(4) ::= true .

% only blood culture test and hospitalization requested, no interim treatment
{ read_param( modified, 3 ) } &
  student : 'specific test'( 'blood culture', 3 ) ::= true &
  student : 'specific test'( stool, 3 ) ::= false &
  student : hospitalization(3) ::= true &
    { existing_metafact( student, 'patient history'(_), true ) } &
    { existing_metafact( student, 'general exam'(_), true ) } &
    { existing_metafact( student, 'general tests'(_), true ) } &
    { \+ existing_metafact( student, 'interim treatment'(_), true ) }

==>
select ( 'interim treatment'(4), 'contact specialist'(4),
        'specific test'( stool, 4 ), 'specific test'('csf exam', 4 ) ) &
        step(3) ::= false & step(4) ::= true .

% only hospitalization requested, no interim treatment and specific tests
{ read_param( modified, 3 ) } &
  student : hospitalization(3) ::= true &
  student : 'specific test'( 'blood culture', 3 ) ::= false &
  student : 'specific test'( stool, 3 ) ::= false &
    { existing_metafact( student, 'patient history'(_), true ) } &
    { existing_metafact( student, 'general exam'(_), true ) } &
    { existing_metafact( student, 'general tests'(_), true ) } &
    { \+ existing_metafact( student, 'interim treatment'(_), true ) }

==>
select ( 'interim treatment'(4), 'contact specialist'(4),
        'specific test'( stool, 4 ), 'specific test'('csf exam', 4 ),
        'specific test'( 'blood culture', 4 ) ) &
        step(3) ::= false & step(4) ::= true .

%%%%%%%% [general exam] [patient history] {W > 10} %%%%%%%%%
%%%%%%%% [patient history] [general exam] {W > 10} %%%%%%%%%
% general tests, interim treatment and hospitalization requested
{ read_param( modified, 3 ) } &
  student : 'general tests'(3) ::= true &
  student : hospitalization(3) ::= true &
  student : 'interim treatment'(3) ::= true &
    { existing_metafact( student, 'patient history'(_), true ) } &
    { existing_metafact( student, 'general exam'(_), true ) }

```

```

==>
select ( 'rehydration oral'(4), antibiotic(4), 'rehydration intravenous'(4),
        'contact specialist'(4), 'specific test'( stool, 4 ),
        'specific test'('csf exam', 4 ), 'specific test'( 'blood culture', 4 ) ) &
        step(3) ::= false & step(4) ::= true .

% general tests and hospitalization requested, no interim treatment
{ read_param( modified, 3 ) } &
  student : 'general tests'(3) ::= true &
  student : hospitalization(3) ::= true &
    { existing_metafact( student, 'patient history'(), true ) } &
    { existing_metafact( student, 'general exam'(), true ) } &
    { \+ existing_metafact( student, 'interim treatment'(), true ) }

==>
select ( 'interim treatment'(4), 'contact specialist'(4),
        'specific test'( stool, 4 ), 'specific test'('csf exam', 4 ),
        'specific test'( 'blood culture', 4 ) ) &
        step(3) ::= false & step(4) ::= true .

% interim treatment and hospitalization requested, no general tests
{ read_param( modified, 3 ) } &
  student : 'interim treatment'(3) ::= true &
  student : hospitalization(3) ::= true &
    { existing_metafact( student, 'patient history'(), true ) } &
    { existing_metafact( student, 'general exam'(), true ) } &
    { \+ existing_metafact( student, 'general tests'(), true ) }

==>
select ( 'general tests'(4), 'contact specialist'(4),
        'rehydration oral'(4), antibiotic(4), 'rehydration intravenous'(4) ) &
        step(3) ::= false & step(4) ::= true .

% only hospitalization requested, no interim treatment and general tests
{ read_param( modified, 3 ) } &
  student : 'interim treatment'(3) ::= false &
  student : hospitalization(3) ::= true &
    { existing_metafact( student, 'patient history'(), true ) } &
    { existing_metafact( student, 'general exam'(), true ) } &
    { \+ existing_metafact( student, 'general tests'(), true ) }

==>
select ( 'interim treatment'(4), 'general tests'(4), 'contact specialist'(4) ) &
        step(3) ::= false & step(4) ::= true .

```

```

%%%%%% [general exam] [hospitalization] %%%%%%
% ----- only history requested, no tests
{ read_param( modified, 3 ) } &
  student : 'patient history'(3) ::= true &
  student : 'general tests'(3) ::= false &
  student : hospitalization(2) ::= true &
  { \+ existing_metafact( student, 'interim treatment'(_, true) ) }
==>
select ( 'general tests'(4), 'contact specialist'(4), 'interim treatment'(4) ) &
  step(3) ::= false & step(4) ::= true .

%-----history and general tests requested
{ read_param( modified, 3 ) } &
  student : 'patient history'(3) ::= true &
  student : 'general tests'(3) ::= true &
  student : hospitalization(2) ::= true &
  { \+ existing_metafact( student, 'interim treatment'(_, true) ) }
==>
select ( 'specific test'( stool, 4 ), 'specific test'('csf exam', 4 ),
  'specific test'( 'blood culture', 4 ), 'contact specialist'(4),
  'interim treatment'(4) ) &
  step(3) ::= false & step(4) ::= true .

% -----Modifications 4
%%%%%% { W =< 10 } %%%%%%
%%%%%% [exam] [history] [interim treatment] %%%%%
%%%%%% [history] [exam] [interim treatment] %%%%%
% ----- general tests requested (history, exam, treatment done)
step(4) ::= true &
  student : 'general tests'(4) ::= true &
  { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& blood_test & urine_test,
  blood_test <- 'red cell'( normal, 4 ) & 'white cell'( normal, 4 ) &
    'cell smear'( normal, 4 ),
  urine_test <- ketones( elevated, 4 ) & 'blood in urine'( absent, 4 ) &
    sugar( absent, 4 ) & proteins( absent, 4 ) ) .

```



```

% % % % %      [exam & history]      [general tests] [interim treatment] % % % % %
% % % % %      [exam & history]      [interim treatment] [general tests] % % % % %
% % % % %      [exam]                [history & general tests] [interim treatment]
% % % % %      [exam]                [history]          [general tests & interim treatment]
% % % % %
% ----- stool test and oral rehydration requested
step(4) ::= true &
  student : 'rehydration oral'(4) ::= true &
  student : 'specific test'( stool, 4 ) ::= true &
    { existing_metafact( student, 'interim treatment'(_), true ) } &
    { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & specific_tests( stool ),
  visible_symptoms(int, b1) <- not diarrhea(4) & not vomiting(4) &
  irritability(neutral, 4 ),
  specific_tests( stool ) <- blood( absent, 4 ) & 'bacterial culture'(positive, 4)
  & parasites( absent, 4 ) & viral( negative, 4 ) ).

% ----- only stool test requested
step(4) ::= true &
  student : 'specific test'( stool, 4 ) ::= true &
    { existing_metafact( student, 'interim treatment'(_), true ) } &
    { \+ existing_metafact( student, 'rehydration oral'(_), true ) } &
    { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& specific_tests( stool ),
  specific_tests( stool ) <- blood( absent, 4 ) & 'bacterial culture'(positive, 4)
  & parasites( absent, 4 ) & viral( negative, 4 ) ).

% ----- only oral rehydration requested
step(4) ::= true &
  student : 'rehydration oral'(4) ::= true &
  student : 'specific test'( stool, 4 ) ::= false &
    { existing_metafact( student, 'interim treatment'(_), true ) } &
    { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
  visible_symptoms(int, b1) <- not diarrhea(4) & not vomiting(4) &
  irritability(neutral, 4 ) ).

```

```

%%%%%% [exam & history] [general tests] [specific test] %%%
%%%%%% [exam] [history & general tests] [specific test] %%%
%%%%%% [history] [exam & general tests] [specific test] %%%
% ----- interim treatment requested
step(4) ::= true &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'interim treatment'(4) ::= true &
  { write_param( modified, 4 ) }
==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
  visible_symptoms(int, b1) <- diarrhea(4) & vomiting(4) &
  'refusal to eat'(4) & irritability(neutral, 4) ).

%%%%%% [exam & history] [general tests] [specific test & treatment]
%%%%%% [exam] [history & general tests] [specific test & treatment]
%%%%%% [history] [exam & general tests] [specific test & treatment]

% ----- oral rehydration requested
step(4) ::= true &
  student : 'rehydration oral'(4) ::= true &
  student : 'specific test'( stool, 3 ) ::= true &
  { existing_metafact( student, 'interim treatment'(_), true ) } &
  { write_param( modified, 4 ) }
==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
  visible_symptoms(int, b1) <- not diarrhea(4) & not vomiting(4) &
  irritability(neutral, 4) ).

%%%%%% [exam] [history] [general tests] %%%
%%%%%% [history] [exam] [general tests] %%%
% ----- interim treatment and stool test requested
step(4) ::= true &
  student : 'specific test'( stool, 4 ) ::= true &
  student : 'interim treatment'(4) ::= true &
  { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & specific_tests( stool ),
  visible_symptoms(int, b1) <- diarrhea(4) & vomiting(4) &
  'refusal to eat'(4) & irritability(neutral, 4),
  specific_tests( stool ) <- blood( absent, 4 ) & 'bacterial culture'(positive, 4)
  & parasites( absent, 4 ) & viral( negative, 4 ) ).

```

```

% ----- only stool test requested, but no interim treatment
step(4) ::= true &
  student : 'specific test'( stool, 4 ) ::= true &
    { \+ existing_metafact( student, 'interim treatment'(_), true ) } &
    { write_param( modified, 4 ) }
==>
modify ( bacteria( int ) <-& specific_tests( stool ),
        specific_tests( stool ) <- blood( absent, 4 ) & 'bacterial culture'(positive, 4)
        & parasites( absent, 4 ) & viral( negative, 4 ) ).

% ----- interim treatment requested, but no specific tests
step(4) ::= true &
  student : 'interim treatment'(4) ::= true &
    { \+ existing_metafact( student, 'specific test'( stool, _ ), true ) } &
    { write_param( modified, 4 ) }
==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
        visible_symptoms(int, b1) <- diarrhea(4) & vomiting(4) &
        'refusal to eat'(4) & irritability(neutral, 4) ).

%%%%%%%%% [exam & history] [tests & treatment] [specific test] %%%%%%%%%
% ----- only rehydration oral requested
step(4) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W =< 10 } &
  student : 'rehydration oral'(4) ::= true &
  student : 'specific test'( stool, T ) ::= true &
    { T < 4 } &
    { write_param( modified, 4 ) }
==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
        visible_symptoms(int, b1) <- not diarrhea(4) & not vomiting(4) &
        irritability(neutral, 4) & not 'dry mouth'(4)) .

%%%%%%%%% [exam & history] [tests & treatment] [oral] %%%%%%%%%
% ----- stool test requested
step(4) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W =< 10 } &
  student : 'rehydration oral'(3) ::= true &
  student : 'specific test'( stool, 4 ) ::= true &
    { write_param( modified, 4 ) }
==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & specific_tests( stool ),
        visible_symptoms(int, b1) <- not diarrhea(4) & not vomiting(4) &
        irritability(low, 4),
        specific_tests( stool ) <- blood( absent, 4 ) & 'bacterial culture'(positive, 4)
        & parasites( absent, 4 ) & viral( negative, 4 ) ).

```

```

% % % % % { W > 10 } % % % % %
% % % % % [exam & history] [G.tests & hosp. & treatment] [S.tests & IV
Reh] % % % % %
% % % % % [exam & history] [G.tests & treatment] [hosp. & S tests & IV Reh]
% % % % %
% ----- stool test requested (blood culture test done)
step(4) ::= true &
    sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
    student : 'specific test'( stool, 4 ) ::= true &
    student : antibiotic(3) ::= true &
    student : 'rehydration intravenous'(3) ::= true &
    student : 'specific test'( 'blood culture', U ) ::= true &
    { U < 4 } &
    student : 'hospitalization'(S) ::= true &
    { S < 4 } &
    { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& specific_tests( stool ),
        specific_tests( stool ) <- blood( absent, 4 ) & 'bacterial culture'(positive, 4)
        & parasites( absent, 4 ) & viral( negative, 4 ) ) .

% ----- blood culture test requested (stool test done)
step(4) ::= true &
    sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
    student : 'specific test'( 'blood culture', 4 ) ::= true &
    student : antibiotic(3) ::= true &
    student : 'rehydration intravenous'(3) ::= true &
    student : 'specific test'( stool, T ) ::= true &
    { T < 4 } &
    student : 'hospitalization'(S) ::= true &
    { S < 4 } &
    { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& specific_tests( 'blood culture' ),
        specific_tests( 'blood culture' ) <- 'blood culture'( positive, 4 ) ) .

% % % % % [exam & history] [G.tests & hosp. & treatment] [specific tests]
% % % % %
% % % % % [exam & history] [G.tests & hosp.] [treatment & specific tests]
% % % % %
% % % % % [exam & history] [G.tests & treatment] [hosp. & specific tests]
% % % % %
% % % % % [exam & history] [G.tests] [hosp. & treatment & specific tests]
% % % % %

```

```

%%%%%% [exam] [history & G.tests & hosp.] [specific tests & treatment]
%%%%%% [exam] [history & G.tests] [hosp. & specific tests & treatment]
%%%%%% [history] [exam & G.tests] [hosp. & specific tests & treatment]

```

```

% ----- only antibiotic and rehydration intravenous requested (both specific tests done)

```

```

step(4) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : antibiotic(4) ::= true &
  student : 'rehydration intravenous'(4) ::= true &
  student : 'specific test'( stool, T ) ::= true &
    { T < 4 } &
  student : 'specific test'( 'blood culture', U ) ::= true &
    { U < 4 } &
  student : 'hospitalization'(S) ::= true &
    { S < 4 } &
  { write_param( modified, 4 ) }

```

```

==>

```

```

modify ( bacteria( int ) <-& visible_symptoms(int, b1),
  visible_symptoms(int, b1) <- not diarrhea(4) & not vomiting(4) &
  irritability(neutral, 4) & not 'dry mouth'(4) ) .

```

```

% ----- stool test, antibiotic, and rehydration intravenous requested

```

```

% (only blood culture test done)

```

```

step(4) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : antibiotic(4) ::= true &
  student : 'rehydration intravenous'(4) ::= true &
  student : 'specific test'( stool, 4 ) ::= true &
  student : 'specific test'( 'blood culture', U ) ::= true &
    { U < 4 } &
  student : 'hospitalization'(S) ::= true &
    { S < 4 } &
  { write_param( modified, 4 ) }

```

```

==>

```

```

modify ( bacteria( int ) <-& visible_symptoms(int, b1) & specific_tests( stool ),
  visible_symptoms(int, b1) <- not diarrhea(4) & not vomiting(4) &
  irritability(neutral, 4) & not 'dry mouth'(4),
  specific_tests( stool ) <- blood( absent, 4 ) & 'bacterial culture'(positive, 4)
  & parasites( absent, 4 ) & viral( negative, 4 ) ) .

```

```

% ----- only antibiotic and rehydration intravenous requested
% (only blood culture test done)
step(4) ::= true &
    sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
    student : antibiotic(4) ::= true &
    student : 'rehydration intravenous'(4) ::= true &
    student : 'specific test'( stool, 4 ) ::= false &
    student : 'specific test'( 'blood culture', U ) ::= true &
    { U < 4 } &
    student : 'hospitalization'(S) ::= true &
    { S < 4 } &
    { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
    visible_symptoms(int, b1) <- not diarrhea(4) & not vomiting(4) &
    irritability(neutral, 4) & not 'dry mouth'(4) ).

% ----- only stool test requested (only blood culture test done)
% ----- but no antibiotic and rehydration intravenous
step(4) ::= true &
    sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
    student : 'specific test'( stool, 4 ) ::= true &
    student : antibiotic(4) ::= false &
    student : 'rehydration intravenous'(4) ::= false &
    student : 'specific test'( 'blood culture', U ) ::= true &
    { U < 4 } &
    student : 'hospitalization'(S) ::= true &
    { S < 4 } &
    { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& specific_tests( stool ),
    specific_tests( stool ) <- blood( absent, 4 ) & 'bacterial culture'(positive, 4)
    & parasites( absent, 4 ) & viral( negative, 4 ) ).

% ----- antibiotic, rehydration intravenous and blood culture test requested
% (only stool test done)
step(4) ::= true &
    sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
    student : antibiotic(4) ::= true &
    student : 'rehydration intravenous'(4) ::= true &
    student : 'specific test'( 'blood culture', 4 ) ::= true &
    student : 'specific test'( stool, T ) ::= true &
    { T < 4 } &
    student : 'hospitalization'(S) ::= true &
    { S < 4 } & { write_param( modified, 4 ) }

```

```

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1)
      & specific_tests( 'blood culture' ),
      visible_symptoms(int, b1) <- not diarrhea(4) & not vomiting(4) &
      irritability(neutral, 4) & not 'dry mouth'(4),
      specific_tests( 'blood culture' ) <- 'blood culture'( positive, 4) ) .

% ----- only rehydration intravenous requested (only stool test done)
% ----- but no blood culture test
step(4) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
  student : antibiotic(4) ::= true &
  student : 'rehydration intravenous'(4) ::= true &
  student : 'specific test'( 'blood culture', 4 ) ::= false &
  student : 'specific test'( stool, T ) ::= true &
  { T < 4 } &
  student : 'hospitalization'(S) ::= true &
  { S < 4 } &
  { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
      visible_symptoms(int, b1) <- not diarrhea(4) & not vomiting(4) &
      irritability(neutral, 4) & not 'dry mouth'(4) ) .

% ----- only blood culture test requested (only stool test done)
% ----- but no rehydration intravenous
step(4) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
  student : 'specific test'( 'blood culture', 4 ) ::= true &
  student : antibiotic(4) ::= false &
  student : 'rehydration intravenous'(4) ::= false &
  student : 'specific test'( stool, T ) ::= true &
  { T < 4 } &
  student : 'hospitalization'(S) ::= true &
  { S < 4 } &
  { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& specific_tests( 'blood culture' ),
      specific_tests( 'blood culture' ) <- 'blood culture'( positive, 4) ) .

% % % % % [exam & history] [G.tests & hosp. & treatment] [IV
Rehydration] % % % % %
% % % % % [exam & history] [G.tests & treatment] [hosp. & IV Rehydration]
% % % % %

```

```

% ----- both specific tests requested
step(4) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'specific test'( stool, 4 ) ::= true &
  student : 'specific test'( 'blood culture', 4 ) ::= true &
  student : antibiotic(3) ::= true &
  student : 'rehydration intravenous'(3) ::= true &
  { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& specific_tests( stool ) & specific_tests( 'blood culture' ),
  specific_tests( stool ) <- blood( absent, 4 ) & 'bacterial culture'(positive, 4)
  & parasites( absent, 4 ) & viral( negative, 4 ),
  specific_tests( 'blood culture' ) <- 'blood culture'( positive, 4 ) ).

% ----- only stool test requested
step(4) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'specific test'( stool, 4 ) ::= true &
  student : 'specific test'( 'blood culture', 4 ) ::= false &
  student : antibiotic(3) ::= true &
  student : 'rehydration intravenous'(3) ::= true &
  { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& specific_tests( stool ),
  specific_tests( stool ) <- blood( absent, 4 ) & 'bacterial culture'(positive, 4)
  & parasites( absent, 4 ) & viral( negative, 4 ) ).

% ----- only blood culture test requested
step(4) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'specific test'( 'blood culture', 4 ) ::= true &
  student : 'specific test'( stool, 4 ) ::= false &
  student : antibiotic(3) ::= true &
  student : 'rehydration intravenous'(3) ::= true &
  { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& specific_tests( 'blood culture' ),
  specific_tests( 'blood culture' ) <- 'blood culture'( positive, 4 ) ).

```



```

% % % % % [exam & history] [G.tests & hosp.] [specific tests]
% % % % %
% % % % % [exam & history] [G.tests] [hosp. & specific tests]
% % % % %

% % % % % [exam] [history & G.tests & hosp.] [specific tests]
% % % % %
% % % % % [exam] [history & G.tests] [hosp. & specific tests]
% % % % %
% % % % % [history] [exam & G.tests] [hosp. & specific tests]
% % % % %

% ----- interim treatment requested (both specific tests done)
step(4) ::= true &
  student : 'interim treatment'(4) ::= true &
  student : hospitalization(S) ::= true &
  { S < 4 } &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'specific test'( 'blood culture', 3 ) ::= true &
  { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
  visible_symptoms(int, b1) <- diarrhea(4) & vomiting(4) &
  'refusal to eat'(4) & irritability(neutral, 4) ).

% ----- interim treatment and stool test requested (only blood culture test done)
step(4) ::= true &
  student : 'interim treatment'(4) ::= true &
  student : 'specific test'( stool, 4 ) ::= true &
  student : hospitalization(S) ::= true &
  { S < 4 } &
  student : 'specific test'( 'blood culture', 3 ) ::= true &
  { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & specific_tests( stool ),
  visible_symptoms(int, b1) <- diarrhea(4) & vomiting(4) &
  'refusal to eat'(4) & irritability(neutral, 4),
  specific_tests( stool ) <- blood( absent, 4 ) & 'bacterial culture'(positive, 4)
  & parasites( absent, 4 ) & viral( negative, 4 ) ).

```

```

% ----- only interim treatment requested (only blood culture test done)
% ----- but no stool test
step(4) ::= true &
  student : 'interim treatment'(4) ::= true &
    student : 'specific test'( stool, 4 ) ::= false &
    student : hospitalization(S) ::= true &
    { S < 4 } &
      student : 'specific test'( 'blood culture', 3 ) ::= true &
      { write_param( modified, 4 ) }
==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
  visible_symptoms(int, b1) <- diarrhea(4) & vomiting(4) &
  'refusal to eat'(4) & irritability(neutral, 4 ) ).

% ----- interim treatment and blood culture test requested (only stool test done)
step(4) ::= true &
  student : 'interim treatment'(4) ::= true &
    student : 'specific test'( 'blood culture', 4 ) ::= true &
    student : 'specific test'( stool, 3 ) ::= true &
    student : hospitalization(S) ::= true &
    { S < 4 } &
      { write_param( modified, 4 ) }
==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1)
  & specific_tests( 'blood culture' ),
  visible_symptoms(int, b1) <- diarrhea(4) & vomiting(4) &
  'refusal to eat'(4) & irritability(neutral, 4),
  specific_tests( 'blood culture' ) <- 'blood culture'( positive, 4 ) ).

% ----- only interim treatment requested (only stool test done)
% ----- but no blood culture test
step(4) ::= true &
  student : 'interim treatment'(4) ::= true &
    student : 'specific test'( 'blood culture', 4 ) ::= false &
    student : 'specific test'( stool, 3 ) ::= true &
    student : hospitalization(S) ::= true &
    { S < 4 } &
      { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
  visible_symptoms(int, b1) <- diarrhea(4) & vomiting(4) &
  'refusal to eat'(4) & irritability(neutral, 4 ) ).

%%%%%%%%%      [exam & history]      [hosp.]      [treatment]      %%%%%%%%%%
%%%%%%%%%      [exam & history]      [treatment]    [hosp.]      %%%%%%%%%%

```

```

%%%%%%%%%      [exam]          [history]      [hosp. & treatment]  %%%%%%%%%%
%%%%%%%%%      [exam]          [history & hosp.]  [treatment]      %%%%%%%%%%
%%%%%%%%%      [history]      [exam]          [hosp. & treatment]  %%%%%%%%%%
% ----- general tests requested
step(4) ::= true &
  student : 'general tests'(4) ::= true &
  student : 'interim treatment'(T) ::= true &
  { T < 4 } &
  student : hospitalization(S) ::= true &
  { S < 4 } &
  { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <- & blood_test & urine_test,
        blood_test <- 'red cell'( normal, 4 ) & 'white cell'( normal, 4 ) &
        'cell smear'( normal, 4 ),
        urine_test <- ketones( elevated, 4 ) & 'blood in urine'( absent, 4 ) &
        'sugar( absent, 4 ) & proteins( absent, 4 ) ).

%%%%%%%%%      [exam]          [hosp.]          [history & G.tests]  %%%%%%%%%%
%%%%%%%%%      general tests were pending at selection 3      %%%
% ----- interim treatment and both specific tests requested
step(4) ::= true &
  { existing_metafact( sick_infant, 'general tests'( pending, 3 ), true ) } &
  sick_infant : 'loss of weight'(W, 'per cent', _ ) ::= true & { W > 10 } &
  student : 'interim treatment'(4) ::= true &
  student : 'specific test'( stool, 4 ) ::= true &
  student : 'specific test'( 'blood culture', 4 ) ::= true &
  { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) < & visible_symptoms(int, b1) & blood_test & urine_test &
        specific_tests( stool ) & specific_tests( 'blood culture' ),
        visible_symptoms(int, b1) <- diarrhea(4) & vomiting(4) & 'refusal to eat'(4) &
        irritability(neutral, 4),
        blood_test <- 'red cell'( normal, 4 ) & 'white cell'( normal, 4 ) &
        'cell smear'( normal, 4 ),
        urine_test <- ketones( elevated, 4 ) & 'blood in urine'( absent, 4 ) &
        'sugar( absent, 4 ) & proteins( absent, 4 ),
        specific_tests( stool ) <- blood( absent, 4 ) & 'bacterial culture'(positive, 4)
        & parasites( absent, 4 ) & viral( negative, 4 ),
        specific_tests( 'blood culture' ) <- 'blood culture'( positive, 4 ) ).

```

```

% ----- interim treatment and only stool test requested
step(4) ::= true &
  { existing_metafact( sick_infant, 'general tests'( pending, 3 ), true ) } &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
  student : 'interim treatment'(4) ::= true &
  student : 'specific test'( stool, 4 ) ::= true &
    student : 'specific test'( 'blood culture', 4 ) ::= false &
    { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & blood_test & urine_test &
  specific_tests( stool ),
  visible_symptoms(int, b1) <- diarrhea(4) & vomiting(4) & 'refusal to eat'(4) &
    irritability(neutral, 4),
  blood_test <- 'red cell'( normal, 4 ) & 'white cell'( normal, 4 ) &
    'cell smear'( normal, 4 ),
  urine_test <- ketones( elevated, 4 ) & 'blood in urine'( absent, 4 ) &
    sugar( absent, 4 ) & proteins( absent, 4 ),
  specific_tests( stool ) <- blood( absent, 4 ) & 'bacterial culture'(positive, 4)
    & parasites( absent, 4 ) & viral( negative, 4 ) ).

% ----- interim treatment and only blood culture test requested
step(4) ::= true &
  { existing_metafact( sick_infant, 'general tests'( pending, 3 ), true ) } &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
  student : 'interim treatment'(4) ::= true &
    student : 'specific test'( 'blood culture', 4 ) ::= tr   &
  student : 'specific test'( stool, 4 ) ::= false &
    { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & blood_test & urine_test &
  specific_tests( 'blood culture' ),
  visible_symptoms(int, b1) <- diarrhea(4) & vomiting(4) & 'refusal to eat'(4) &
    irritability(neutral, 4),
  blood_test <- 'red cell'( normal, 4 ) & 'white cell'( normal, 4 ) &
    'cell smear'( normal, 4 ),
  urine_test <- ketones( elevated, 4 ) & 'blood in urine'( absent, 4 ) &
    sugar( absent, 4 ) & proteins( absent, 4 ),
  specific_tests( 'blood culture' ) <- 'blood culture'( positive, 4 ) ).

```

```

% ----- both specific tests requested only
step(4) ::= true &
  { existing_metafact( sick_infant, 'general tests'( pending, 3 ), true ) } &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
  student : 'specific test'( stool, 4 ) ::= true &
    student : 'specific test'( 'blood culture', 4 ) ::= true &
  student : 'interim treatment'(4) ::= false &
    { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& blood_test & urine_test & specific_tests( stool ) &
  specific_tests( 'blood culture' ),
  blood_test <- 'red cell'( normal, 4 ) & 'white cell'( normal, 4 ) &
    'cell smear'( normal, 4 ),
  urine_test <- ketones( elevated, 4 ) & 'blood in urine'( absent, 4 ) &
    sugar( absent, 4 ) & proteins( absent, 4 ),
  specific_tests( stool ) <- blood( absent, 4 ) & 'bacterial culture'(positive, 4)
    & parasites( absent, 4 ) & viral( negative, 4 ),
  specific_tests( 'blood culture' ) <- 'blood culture'( positive, 4 ) ).

% ----- only stool test requested
step(4) ::= true &
  { existing_metafact( sick_infant, 'general tests'( pending, 3 ), true ) } &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
  student : 'specific test'( stool, 4 ) ::= true &
    student : 'specific test'( 'blood culture', 4 ) ::= false &
  student : 'interim treatment'(4) ::= false &
    { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& blood_test & urine_test & specific_tests( stool ),
  blood_test <- 'red cell'( normal, 4 ) & 'white cell'( normal, 4 ) &
    'cell smear'( normal, 4 ),
  urine_test <- ketones( elevated, 4 ) & 'blood in urine'( absent, 4 ) &
    sugar( absent, 4 ) & proteins( absent, 4 ),
  specific_tests( stool ) <- blood( absent, 4 ) & 'bacterial culture'(positive, 4)
    & parasites( absent, 4 ) & viral( negative, 4 ) ).

% ----- only blood culture test requested
step(4) ::= true &
  { existing_metafact( sick_infant, 'general tests'( pending, 3 ), true ) } &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
    student : 'specific test'( 'blood culture', 4 ) ::= true &
  student : 'specific test'( stool, 4 ) ::= false &
  student : 'interim treatment'(4) ::= false &
    { write_param( modified, 4 ) }

```

```

==>
modify ( bacteria( int ) <-& blood_test & urine_test & specific_tests( 'blood culture' ),
        blood_test <- 'red cell'( normal, 4 ) & 'white cell'( normal, 4 ) &
          'cell smear'( normal, 4 ),
        urine_test <- ketones( elevated, 4 ) & 'blood in urine'( absent, 4 ) &
          sugar( absent, 4 ) & proteins( absent, 4 ),
        specific_tests( 'blood culture' ) <- 'blood culture'( positive, 4 ) ).

% ----- only interim treatment requested
step(4) ::= true &
  { existing_metafact( sick_infant, 'general tests'( pending, 3 ), true ) } &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
  student : 'interim treatment'(4) ::= true &
  student : 'specific test'( stool, 4 ) ::= false &
  student : 'specific test'( 'blood culture', 4 ) ::= false &
  { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & blood_test & urine_test,
        visible_symptoms(int, b1) <- diarrhea(4) & vomiting(4) & 'refusal to eat'(4) &
          irritability(neutral, 4),
        blood_test <- 'red cell'( normal, 4 ) & 'white cell'( normal, 4 ) &
          'cell smear'( normal, 4 ),
        urine_test <- ketones( elevated, 4 ) & 'blood in urine'( absent, 4 ) &
          sugar( absent, 4 ) & proteins( absent, 4 ) ).

%%%%%%%% [exam & history] [hosp. & treatment] [G.tests] %%%%%%%%%
%%%%%%%% [exam & history] [hosp. & G.tests] [treatment] %%%%%%%%%
%%%%%%%% [exam & history] [hosp.] [G.tests & treatment] %%%%%%%%%
%%%%%%%% [exam & history] [G.tests] [hosp. & treatment] %%%%%%%%%
%%%%%%%% [exam & history] [treatment] [hosp. & G.tests] %%%%%%%%%
%%%%%%%% [exam & history] [G.tests & treatment] [hosp.] %%%%%%%%%
%%%%%%%% [exam] [history & G.tests & hosp.] [treatment] %%%%%%%%%
%%%%%%%% [exam] [history & G.tests] [hosp. & treatment] %%%%%%%%%
%%%%%%%% [exam] [history & hosp.] [G.tests & treatment] %%%%%%%%%
%%%%%%%% [exam] [history] [hosp. & G.tests & treatment] %%%%%%%%%
%%%%%%%% [history] [exam & G.tests] [hosp. & treatment] %%%%%%%%%
%%%%%%%% [history] [exam] [G.test & hosp. & treatment] %%%%%%%%%
% ----- antibiotic, intravenous rehydration and both specific tests requested
step(4) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
  student : antibiotic(4) ::= true &
  student : 'rehydration intravenous'(4) ::= true &
  student : 'specific test'( stool, 4 ) ::= true &
  student : 'specific test'( 'blood culture', 4 ) ::= true &
  { write_param( modified, 4 ) }

```

```

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & specific_tests( stool )
      & specific_tests( 'blood culture' ),
      visible_symptoms(int, b1) <- not diarrhea(4) & not vomiting(4) &
      irritability(low, 4),
      specific_tests( stool ) <- blood( absent, 4 ) & 'bacterial culture'(positive, 4)
      & parasites( absent, 4 ) & viral( negative, 4 ),
      specific_tests( 'blood culture' ) <- 'blood culture'( positive, 4 ) ).

% ----- antibiotic, intravenous rehydration and only stool test requested
step(4) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
  student : antibiotic(4) ::= true &
  student : 'rehydration intravenous'(4) ::= true &
  student : 'specific test'( stool, 4 ) ::= true &
  student : 'specific test'( 'blood culture', 4 ) ::= false &
  { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & specific_tests( stool ),
      visible_symptoms(int, b1) <- not diarrhea(4) & not vomiting(4) &
      irritability(low, 4),
      specific_tests( stool ) <- blood( absent, 4 ) & 'bacterial culture'(positive, 4)
      & parasites( absent, 4 ) & viral( negative, 4 ) ).

% ----- antibiotic, intravenous rehydration and only blood culture test requested
step(4) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
  student : antibiotic(4) ::= true &
  student : 'rehydration intravenous'(4) ::= true &
  student : 'specific test'( 'blood culture', 4 ) ::= true &
  student : 'specific test'( stool, 4 ) ::= false &
  { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1)
      & specific_tests( 'blood culture' ),
      visible_symptoms(int, b1) <- not diarrhea(4) & not vomiting(4) &
      irritability(low, 4),
      specific_tests( 'blood culture' ) <- 'blood culture'( positive, 4 ) ).

% ----- only both specific tests requested, no intravenous rehydration, antibiotic
step(4) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
  student : 'specific test'( stool, 4 ) ::= true &
  student : 'specific test'( 'blood culture', 4 ) ::= true &
  student : antibiotic(4) ::= false &
  student : 'rehydration intravenous'(4) ::= false &

```

```

{ write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& specific_tests( stool )
      & specific_tests( 'blood culture' ),
      specific_tests( stool ) <- blood( absent, 4 ) & 'bacterial culture'(positive, 4)
      & parasites( absent, 4 ) & viral( negative, 4 ),
      specific_tests( 'blood culture' ) <- 'blood culture'( positive, 4 ) ).

% ----- only stool test requested, no intravenous rehydration and antibiotic
step(4) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
  student : 'specific test'( stool, 4 ) ::= true &
  student : antibiotic(4) ::= false &
  student : 'rehydration intravenous'(4) ::= false &
  student : 'specific test'( 'blood culture', 4 ) ::= false &
  { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& specific_tests( stool ),
      specific_tests( stool ) <- blood( absent, 4 ) & 'bacterial culture'(positive, 4)
      & parasites( absent, 4 ) & viral( negative, 4 ) ).

% ----- only blood culture test requested, no intravenous rehydration
step(4) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
  student : 'specific test'( 'blood culture', 4 ) ::= true &
  student : 'specific test'( stool, 4 ) ::= false &
  student : antibiotic(4) ::= false &
  student : 'rehydration intravenous'(4) ::= false &
  { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& specific_tests( 'blood culture' ),
      specific_tests( 'blood culture' ) <- 'blood culture'( positive, 4 ) ).

% ----- only intravenous rehydration requested, none of specific tests
step(4) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
  student : antibiotic(4) ::= true &
  student : 'rehydration intravenous'(4) ::= true &
  student : 'specific test'( stool, 4 ) ::= false &
  student : 'specific test'( 'blood culture', 4 ) ::= false &
  { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
      visible_symptoms(int, b1) <- not diarrhea(4) & not vomiting(4) &
      irritability(low, 4 ) ).

```


%%%%%	[exam & history]	[hosp.]	[G.tests]	%%%%%
%%%%%	[exam & history]	[G.tests]	[hosp.]	%%%%%
%%%%%	[exam]	[history & G.tests]	[hosp.]	%%%%%
%%%%%	[exam]	[history & hosp.]	[G.tests]	%%%%%
%%%%%	[exam]	[history]	[hosp. & G.tests]	%%%%%
%%%%%	[history]	[exam & G.tests]	[hosp.]	%%%%%
%%%%%	[history]	[exam]	[G.tests & hosp.]	%%%%%

% ----- both specific tests and interim treatment requested

step(4) ::= true &

sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
 { \+ existing_metafact(sick_infant, 'general tests'(pending, 3), true) } &
 student : 'specific test'(stool, 4) ::= true &
 student : 'specific test'('blood culture', 4) ::= true &
 student : 'interim treatment'(4) ::= true &
 { write_param(modified, 4) }

==>

modify (bacteria(int) <-& visible_symptoms(int, b1) & specific_tests(stool)
 & specific_tests('blood culture'),
 visible_symptoms(int, b1) <- diarrhea(4) & vomiting(4) & 'refusal to eat'(4) &
 irritability(neutral, 4),
 specific_tests(stool) <- blood(absent, 4) & 'bacterial culture'(positive, 4)
 & parasites(absent, 4) & viral(negative, 4),
 specific_tests('blood culture') <- 'blood culture'(positive, 4)).

% ----- only stool test and interim treatment requested

step(4) ::= true &

sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
 { \+ existing_metafact(sick_infant, 'general tests'(pending, 3), true) } &
 student : 'specific test'(stool, 4) ::= true &
 student : 'interim treatment'(4) ::= true &
 student : 'specific test'('blood culture', 4) ::= false &
 { write_param(modified, 4) }

==>

modify (bacteria(int) <-& visible_symptoms(int, b1) & specific_tests(stool),
 visible_symptoms(int, b1) <- diarrhea(4) & vomiting(4) & 'refusal to eat'(4) &
 irritability(neutral, 4),
 specific_tests(stool) <- blood(absent, 4) & 'bacterial culture'(positive, 4)
 & parasites(absent, 4) & viral(negative, 4)).

```

% ----- only blood culture test and interim treatment requested
step(4) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent' , _) ::= true & { W > 10 } &
  { \+ existing_metafact( sick_infant, 'general tests'( pending, 3 ), true ) } &
  student : 'specific test'( 'blood culture', 4 ) ::= true &
  student : 'interim treatment'(4) ::= true &
  student : 'specific test'( stool, 4 ) ::= false &
  { write_param( modified, 4 ) }
==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1)
  & specific_tests( 'blood culture' ),
  visible_symptoms(int, b1) <- diarrhea(4) & vomiting(4) & 'refusal to eat'(4) &
  irritability(neutral, 4),
  specific_tests( 'blood culture' ) <- 'blood culture'( positive, 4 ) ).

% ----- only both specific tests requested, no interim treatment
step(4) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent' , _) ::= true & { W > 10 } &
  { \+ existing_metafact( sick_infant, 'general tests'( pending, 3 ), true ) } &
  student : 'specific test'( stool, 4 ) ::= true &
  student : 'specific test'( 'blood culture', 4 ) ::= true &
  student : 'interim treatment'(4) ::= false &
  { write_param( modified, 4 ) }
==>
modify ( bacteria( int ) <-& specific_tests( stool )
  & specific_tests( 'blood culture' ),
  specific_tests( stool ) <- blood( absent, 4 ) & 'bacterial culture'(positive, 4)
  & parasites( absent, 4 ) & viral( negative, 4 ),
  specific_tests( 'blood culture' ) <- 'blood culture'( positive, 4 ) ).

% ----- only stool test requested, no interim treatment
step(4) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent' , _) ::= true & { W > 10 } &
  { \+ existing_metafact( sick_infant, 'general tests'( pending, 3 ), true ) } &
  student : 'specific test'( stool, 4 ) ::= true &
  student : 'specific test'( 'blood culture', 4 ) ::= false &
  student : 'interim treatment'(4) ::= false &
  { write_param( modified, 4 ) }
==>
modify ( bacteria( int ) <-& specific_tests( stool ),
  specific_tests( stool ) <- blood( absent, 4 ) & 'bacterial culture'(positive, 4)
  & parasites( absent, 4 ) & viral( negative, 4 ) ).

```

```

% ----- only blood culture test requested, no interim treatment
step(4) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  { + existing_metafact( sick_infant, 'general tests'( pending, 3 ), true ) } &
  student : 'specific test'( 'blood culture', 4 ) ::= true &
  student : 'specific test'( stool, 4 ) ::= false &
  student : 'interim treatment'(4) ::= false &
  { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& specific_tests( 'blood culture' ),
        specific_tests( 'blood culture' ) <- 'blood culture'( positive, 4 ) ).

% -----only interim treatment requested, none of specific tests
step(4) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  { \+ existing_metafact( sick_infant, 'general tests'( pending, 3 ), true ) } &
  student : 'interim treatment'(4) ::= true &
  student : 'specific test'( stool, 4 ) ::= false &
  student : 'specific test'( 'blood culture', 4 ) ::= false &
  { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
        visible_symptoms(int, b1) <- diarrhea(4) & vomiting(4) & 'refusal to eat'(4) &
        irritability(neutral, 4) ).

%%%%%%%%%      [exam]          [history]      [hosp.]      %%%%%%%%%
%%%%%%%%%      [exam]          [hosp.]        [history]     %%%%%%%%%
%%%%%%%%%      [history]       [exam]          [hosp.]       %%%%%%%%%
% ----- general tests and interim treatment requested
step(4) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'general tests'(4) ::= true &
  student : 'interim treatment'(4) ::= true &
  { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & blood_test & urine_test,
        visible_symptoms(int, b1) <- diarrhea(4) & vomiting(4) & 'refusal to eat'(4) &
        irritability(neutral, 4),
        blood_test <- 'red cell'( normal, 4 ) & 'white cell'( normal, 4 ) &
        'cell smear'( normal, 4 ),
        urine_test <- ketones( elevated, 4 ) & 'blood in urine'( absent, 4 ) &
        sugar( absent, 4 ) & proteins( absent, 4 ) ).

```

```

% ----- general tests requested only, no interim treatment
step(4) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
  student : 'general tests'(4) ::= true &
  student : 'interim treatment'(4) ::= false &
    { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& blood_test & urine_test,
  blood_test <- 'red cell'( normal, 4 ) & 'white cell'( normal, 4 ) &
    'cell smear'( normal, 4 ),
  urine_test <- ketones( elevated, 4 ) & 'blood in urine'( absent, 4 ) &
    sugar( absent, 4 ) & proteins( absent, 4 ) ).

% -----only interim treatment requested, no general tests
step(4) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
  student : 'interim treatment'(4) ::= true &
  student : 'general tests'(4) ::= false &
    { write_param( modified, 4 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
  visible_symptoms(int, b1) <- diarrhea(4) & vomiting(4) & 'refusal to eat'(4) &
    irritability(neutral, 4 ) ).

%----- Selections 5

%%%%%%%% { W =< 10 } %%%%%%%%%

%%%%%%%% [exam & history] [[G. tests & treatment] [S.test]
                                [Oral Reh] %%%%%%%%%
%%%%%%%% [exam & history] [[G. tests & treatment] [Oral Reh]
                                [S.test] %%%%%%%%%
%%%%%%%% [exam & history] [treatment] [G. tests] [S.test & Oral Reh]
                                %%%%%%%%%
%%%%%%%% [exam & history] [G. tests] [treatment] [S.test & Oral Reh]
                                %%%%%%%%%
%%%%%%%% [exam & history] [G. tests] [treatment & S.test] [Oral Reh]
                                %%%%%%%%%

% ----- correct treatment and specific test done
{ read_param( modified, 4 ) } &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W =< 10 } &
  student : 'specific test'( stool, U ) ::= true &
    { U =< 4 } &
  student : 'rehydration oral'(T) ::= true &
    { T =< 4 }

```

==>

```
select ( 'virus of intestinal tract'(5), 'bacterial infection of intestinal tract'(5),
        'virus of neurological tract'(5) ) &
        step(4) ::= false & step(5) ::= true .
```

%%%	[exam & history]	[treatment]	[G. tests]	[S.test]	%%%
%%%	[exam & history]	[G. tests]	[treatment]	[S.test]	%%%
%%%	[exam]	[history & G. tests]	[treatment]	[S.test]	%%%
%%%	[exam]	[history]	[G. tests & treatment]	[S.test]	%%%
%%%	[exam]	[history]	[G. tests]	[treatment & S.test]	%%%
%%%	[history]	[exam & G. tests]	[treatment]	[S.test]	%%%
%%%	[history]	[exam]	[G. tests & treatment]	[S.test]	%%%
%%%	[history]	[exam]	[G. tests]	[treatment & S.test]	%%%

% ----- specific test done, except oral rehydration

```
{ read_param( modified, 4 ) } &
  sick_infant : 'loss of weight'(W, 'per cent', _ ) ::= true & { W =< 10 } &
  student : 'specific test'( stool, U ) ::= true &
    { U =< 4 } &
    { existing_metafact( student, 'interim treatment'(_), true ) } &
    { existing_metafact( student, 'general'(_), true ) } &
    { \+ existing_metafact( student, 'rehydration oral'(_), true ) }
```

==>

```
select ( hospitalization(5), 'contact specialist'(5), 'rehydration oral'(5),
        antibiotic(5), 'rehydration intravenous'(5) ) &
        step(4) ::= false & step(5) ::= true .
```

%%%	[exam & history]	[treatment]	[G. tests]	[Oral Reh]	%%%
%%%	[exam & history]	[G. tests]	[treatment]	[Oral Reh]	%%%
%%%	[exam]	[history & G. tests]	[treatment]	[Oral Reh]	%%%
%%%	[exam]	[history]	[G. tests & treatment]	[Oral Reh]	%%%
%%%	[history]	[exam & G. tests]	[treatment]	[Oral Reh]	%%%
%%%	[history]	[exam]	[G. tests & treatment]	[Oral Reh]	%%%

% ----- only oral rehydration requested, no specific test

```
{ read_param( modified, 4 ) } &
  student : 'rehydration oral'(4) ::= true &
    { \+ existing_metafact( student, 'specific test'( stool, _ ), true ) }
```

==>

```
select ( 'specific test'( stool, 5 ), 'specific test'('csf exam', 5 ),
        'specific test'( 'blood culture', 5 ), antibiotic(5),
        'rehydration intravenous'(5), hospitalization(5) ) &
        step(4) ::= false & step(5) ::= true .
```

```

%%%%[exam & history]      [G. tests]      [stool test]      [treatment]
      %%%
%%[exam]      [history & G. tests] [stool test]      [treatment] %%%
%%[history]      [exam & G. tests]      [stool test]      [treatment] %%%
% ----- interim treatment requested, no stool test
{ read_param( modified, 4 ) } &
  student : 'interim treatment'(4) ::= true &
  student : 'specific test'( stool, 3 ) ::= true
==>
select ( 'specific test'('csf exam', 5 ), 'specific test'( 'blood culture', 5 ),
  'rehydration oral'(5), antibiotic(5), 'rehydration intravenous'(5),
  hospitalization(5), 'contact specialist'(5) ) &
  step(4) ::= false & step(5) ::= true .

%%[exam]      [history]      [G. tests]      [stool test] %%%
%%[history]      [exam]      [G. tests]      [stool test] %%%
% ----- stool test requested, no interim treatment
{ read_param( modified, 4 ) } &
  student : 'specific test'( stool, 4 ) ::= true &
  student : 'interim treatment'(4) ::= false
==>
select ( 'specific test'('csf exam', 5 ), 'specific test'( 'blood culture', 5 ),
  'interim treatment'(5), hospitalization(5), 'contact specialist'(5) ) &
  step(4) ::= false & step(5) ::= true .

%%[exam]      [history]      [G. tests]      [treatment] %%%
%%[history]      [exam]      [G. tests]      [treatment] %%%
% ----- interim treatment requested
{ read_param( modified, 4 ) } &
  student : 'interim treatment'(4) ::= true &
  student : 'specific test'( stool, 4 ) ::= false
==>
select ( 'specific test'('csf exam', 5 ), 'specific test'( 'blood culture', 5 ),
  'rehydration oral'(5), antibiotic(5), 'rehydration intravenous'(5),
  'specific test'( stool, 5 ), hospitalization(5), 'contact specialist'(5) ) &
  step(4) ::= false & step(5) ::= true .

%%[exam]      [history]      [treatment]      [G. tests] %%%
%%[history]      [exam]      [treatment]      [G. tests] %%%
% ----- general tests requested
{ read_param( modified, 4 ) } &
  student : 'general tests'(4) ::= true &
  student : 'interim treatment'(3) ::= true

```

==>

```
select ( 'specific test'('csf exam', 5 ), 'specific test'('blood culture', 5 ),
        'specific test'('stool', 5 ), 'rehydration oral'(5),
        antibiotic(5), 'rehydration intravenous'(5), hospitalization(5) ) &
        step(4) ::= false & step(5) ::= true .
```

%%%%%	{ W > 10 }	%%%%%%%%	
%%%%%	[exam & history]	[G.tests & treatment]	[Hosp.] %%%%%
%%%%%	[exam & history]	[treatment]	[Hosp. & G.tests] %%%%%
%%%%%	[exam & history]	[G.tests]	[Hosp. & treatment] %%%%%
%%%%%	[exam & history]	[Hosp.]	[G.tests & treatment] %%%%%
%%%%%	[exam & history]	[Hosp. & G.tests]	[treatment] %%%%%
%%%%%	[exam & history]	[Hosp. & treatment]	[G.tests] %%%%%

%%%%%	[exam]	[history]	[Hosp. & G.tests & treatment]
%%%%%%%%			
%%%%%	[exam]	[history & Hosp.]	[G.tests & treatment] %%%%%
%%%%%	[exam]	[history & Hosp. & G.tests]	[treatment] %%%%%
%%%%%	[exam]	[history & G.tests]	[Hosp. & treatment] %%%%%
%%%%%%%%	[history]	[exam]	[Hosp. & G.tests & treatment]

%%%%%%%%	[history]	[exam & G.tests]	[Hosp. & treatment] %%%%%
%% IT, ST, IT&ST			

% ----- correct treatment (specific tests earlier)

```
{ read_param( modified, 4 ) } &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'specific test'('stool', T) ::= true &
    { T =< 4 } &
  student : 'specific test'('blood culture', U) ::= true &
    { U =< 4 } &
  student : antibiotic(S) ::= true &
    { S =< 4 } &
  student : 'rehydration intravenous'(X) ::= true &
    { X =< 4 } &
    { existing_metafact( student, hospitalization(_), true ) }
```

==>

```
select ( 'virus of intestinal tract'(5), 'bacterial infection of intestinal tract'(5),
        'virus of neurological tract'(5) ) &
        step(4) ::= false & step(5) ::= true .
```

```

% ----- correct treatment and only stool test done
{ read_param( modified, 4 ) &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
  student : 'specific test'( stool, U ) ::= true &
    { U =< 4 } &
  student : antibiotic(S) ::= true &
    { S =< 4 } &
  student : 'rehydration intravenous'(T) ::= true &
    { T =< 4 } &
  student : 'specific test'('blood culture', 4) ::= false &
    { existing_metafact( student, hospitalization(_), true ) }
==>
select ( 'rehydration oral'(5), 'contact specialist'(5),
  'specific test'('csf exam', 5 ), 'specific test'('blood culture', 5 ) ) &
  step(4) ::= false & step(5) ::= true .

% ----- correct treatment and only blood culture test done
{ read_param( modified, 4 ) &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
  student : 'specific test'('blood culture', X) ::= true &
    { X =< 4 } &
  student : 'rehydration intravenous'(T) ::= true &
    { T =< 4 } &
  student : 'specific test'( stool, 4 ) ::= false &
    { existing_metafact( student, hospitalization(_), true ) }
==>
select ( antibiotic(5), 'rehydration oral'(5), 'contact specialist'(5),
  'specific test'('csf exam', 5 ), 'specific test'( stool, 5 ) ) &
  step(4) ::= false & step(5) ::= true .

% ----- both specific tests done, except intravenous rehydration
{ read_param( modified, 4 ) &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
  student : 'specific test'( stool, U ) ::= true &
    { U =< 4 } &
  student : 'specific test'('blood culture', X) ::= true &
    { X =< 4 } &
    { existing_metafact( student, 'interim treatment'(_), true ) } &
    { \+ existing_metafact( student, 'rehydration intravenous'(_), true ) } &
    { existing_metafact( student, hospitalization(_), true ) }
==>
select ( 'contact specialist'(5), 'rehydration oral'(5), antibiotic(5),
  'specific test'('csf exam', 5 ), 'rehydration intravenous'(5) ) &
  step(4) ::= false & step(5) ::= true .

```



```

%% %% %% %% [exam & history] [treatment] [Hosp.] %%% %%
%% %% %% %% [exam & history] [Hosp.] [treatment] %%% %%
%% %% %% %% [exam] [history] [Hosp. & treatment] %%% %%
%% %% %% %% [exam] [history & Hosp.] [treatment] %%% %%
%% %% %% %% [history] [exam] [Hosp. & treatment] %%% %%
% ----- general tests requested
{ read_param( modified, 4 ) } &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
  student : 'general tests'(4) ::= true &
  student : 'interim treatment'(T) ::= true &
  { T < 4 } &
  student : hospitalization(T) ::= true &
  { T < 4 }
==>
select ( 'specific test'( stool, 5 ), 'specific test'('csf exam' , 5 ),
  'specific test'( 'blood culture', 5 ), 'rehydration oral'(5),
  antibiotic(5), 'rehydration intravenous'(5), 'contact specialist'(5) ) &
  step(4) ::= false & step(5) ::= true .

%% %% %% %% [exam & history] [G.tests] [Hosp. & S.tests] %%% %%
%% %% %% %% [exam & history] [Hosp. & G.tests] [S.tests] %%% %%
%% %% %% %% [exam] [history & Hosp. & G.tests] [S.tests] %%% %%
%% %% %% %% [exam] [history & G.tests] [Hosp. & S.tests] %%% %%
%% %% %% %% [history] [exam & G.tests] [Hosp. & S.tests] %%% %%
% ----- interim treatment requested (both tests done)
{ read_param( modified, 4 ) } &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
  student : 'interim treatment'(4) ::= true &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'specific test'('blood culture', 3) ::= true
==>
select ( 'specific test'('csf exam', 5 ), 'rehydration oral'(5), antibiotic(5),
  'rehydration intravenous'(5), 'contact specialist'(5) ) &
  step(4) ::= false & step(5) ::= true .

% ----- only interim treatment requested, blood culture not
{ read_param( modified, 4 ) } &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
  student : 'interim treatment'(4) ::= true &
  student : 'specific test'( stool, 3 ) ::= true &
  student : 'specific test'('blood culture', 4) ::= false

```

```

==>
select ( 'specific test'('csf exam', 5 ), 'contact specialist'(5),
        'specific test'( 'blood culture', 5 ),
        'rehydration oral'(5), antibiotic(5), 'rehydration intravenous'(5) ) &
        step(4) ::= false & step(5) ::= true .

% ----- interim treatment and blood culture requested
{ read_param( modified, 4) } &
    sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & {W > 10} &
    student : 'interim treatment'(4) ::= true &
    student : 'specific test'( stool, 3 ) ::= true &
    student : 'specific test'('blood culture', 4) ::= true
==>
select ( 'specific test'('csf exam', 5 ), 'contact specialist'(5), antibiotic(5),
        'rehydration oral'(5), 'rehydration intravenous'(5) ) &
        step(4) ::= false & step(5) ::= true .

% ----- only interim treatment requested, stool not
{ read_param( modified, 4) } &
    sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & {W > 10} &
    student : 'interim treatment'(4) ::= true &
    student : 'specific test'( stool, 4 ) ::= false &
    student : 'specific test'('blood culture', 3) ::= true
==>
select ( 'specific test'('csf exam', 5 ), 'contact specialist'(5), 'rehydration oral'(5),
        'specific test'( stool, 5 ), antibiotic(5), 'rehydration intravenous'(5) ) &
        step(4) ::= false & step(5) ::= true .

% ----- interim treatment and stool test requested
{ read_param( modified, 4) } &
    sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & {W > 10} &
    student : 'interim treatment'(4) ::= true &
    student : 'specific test'( stool, 4 ) ::= true &
    student : 'specific test'('blood culture', 3) ::= true
==>
select ( 'specific test'('csf exam', 5 ), 'contact specialist'(5),
        'rehydration oral'(5), antibiotic(5), 'rehydration intravenous'(5) ) &
        step(4) ::= false & step(5) ::= true .

```

```

%%%%%%%%% [exam & history] [G.tests] [Hosp.] %%%%%%%%%
%%%%%%%%% [exam & history] [Hosp.] [G.tests] %%%%%%%%%
%%%%%%%%% [exam] [history] [Hosp. & G.tests] %%%%%%%%%
%%%%%%%%% [exam] [Hosp.] [history & G.tests] %%%%%%%%%
%%%%%%%%% [exam] [history & Hosp.] [G.tests] %%%%%%%%%
%%%%%%%%% [exam] [history & G.tests] [Hosp.] %%%%%%%%%
%%%%%%%%% [history] [exam] [Hosp. & G.tests] %%%%%%%%%
%%%%%%%%% [history] [exam & G.tests] [Hosp.] %%%%%%%%%
% IT, ST, IT&ST
% ----- only interim treatment requested, none of specific tests
{ read_param( modified, 4 ) } &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'interim treatment'(4) ::= true &
  student : 'specific test'( stool, 4 ) ::= false &
  student : 'specific test'('blood culture', 4) ::= false
==>
select ( 'specific test'('csf exam', 5 ), 'contact specialist'(5),
  'specific test'('blood culture', 5 ), 'specific test'( stool, 5 ),
  'rehydration oral'(5), antibiotic(5), 'rehydration intravenous'(5) ) &
  step(4) ::= false & step(5) ::= true .

% ----- both specific tests requested, but not interim treatment
{ read_param( modified, 4 ) } &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'specific test'( stool, 4 ) ::= true &
  student : 'specific test'('blood culture', 4) ::= true &
  student : 'interim treatment'(4) ::= false
==>
select ( 'specific test'('csf exam', 5 ), 'contact specialist'(5),
  'interim treatment'(5) ) &
  step(4) ::= false & step(5) ::= true .

% ----- only stool test requested, but not blood culture and interim treatment
{ read_param( modified, 4 ) } &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : 'specific test'( stool, 4 ) ::= true &
  student : 'specific test'('blood culture', 4) ::= false &
  student : 'interim treatment'(4) ::= false
==>
select ( 'specific test'('csf exam', 5 ), 'contact specialist'(5),
  'specific test'('blood culture', 5 ), 'interim treatment'(5) ) &
  step(4) ::= false & step(5) ::= true .

```

```

% ----- only blood culture test requested, but not stool and interim treatment
{ read_param( modified, 4 ) } &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & {W > 10} &
  student : 'specific test'('blood culture', 4) ::= true &
  student : 'specific test'( stool, 4 ) ::= false &
  student : 'interim treatment'(4) ::= false
==>
select ( 'specific test'('csf exam', 5 ), 'contact specialist'(5),
  'specific test'(stool, 5 ), 'interim treatment'(5) ) &
  step(4) ::= false & step(5) ::= true .

% ----- interim treatment and both specific tests requested
{ read_param( modified, 4 ) } &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & {W > 10} &
  student : 'interim treatment'(4) ::= true &
  student : 'specific test'( stool, 4 ) ::= true &
  student : 'specific test'('blood culture', 4) ::= true
==>
select ( 'specific test'('csf exam', 5 ), 'contact specialist'(5),
  'rehydration oral'(5), antibiotic(5), 'rehydration intravenous'(5) ) &
  step(4) ::= false & step(5) ::= true .

% ----- interim treatment and stool test requested
% ----- blood culture not
{ read_param( modified, 4 ) } &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & {W > 10} &
  student : 'interim treatment'(4) ::= true &
  student : 'specific test'( stool, 4 ) ::= true &
  student : 'specific test'('blood culture', 4) ::= false
==>
select ( 'specific test'('csf exam', 5 ), 'contact specialist'(5), 'rehydration oral'(5),
  'specific test'( 'blood culture', 5 ), antibiotic(5),
  'rehydration intravenous'(5) ) &
  step(4) ::= false & step(5) ::= true .

% ----- interim treatment and blood culture test requested
% ----- stool not
{ read_param( modified, 4 ) } &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & {W > 10} &
  student : 'interim treatment'(4) ::= true &
  student : 'specific test'('blood culture', 4) ::= true &
  student : 'specific test'( stool, 4 ) ::= false

```

```

==>
select ( 'specific test'('csf exam', 5 ), 'contact specialist'(5), 'rehydration oral'(5),
        'specific test'(stool, 5 ), antibiotic(5), 'rehydration intravenous'(5) ) &
        step(4) ::= false & step(5) ::= true .

```

```

%%%%%%%%%      [exam]          [history]      [Hosp.]      %%%%%%%%%%
%%%%%%%%%      [exam]          [Hosp.]        [history]     %%%%%%%%%%
%%%%%%%%%      [history]       [exam]          [Hosp.]       %%%%%%%%%%

```

% IT, GT, IT>

% ----- only interim treatment requested

```

{ read_param( modified, 4 ) } &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & {W > 10} &
  student : 'interim treatment'(4) ::= true &
  student : 'general test'(4) ::= false

```

==>

```

select ( 'contact specialist'(5), 'rehydration oral'(5),
        'general test'(5), antibiotic(5), 'rehydration intravenous'(5) ) &
        step(4) ::= false & step(5) ::= true .

```

% ----- only general test requested

```

{ read_param( modified, 4 ) } &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & {W > 10} &
  student : 'general test'(4) ::= true &
  student : 'interim treatment'(4) ::= false

```

==>

```

select ( 'specific test'('csf exam', 5 ), 'specific test'('blood culture', 5),
        'specific test'(stool, 5 ), 'contact specialist'(5), 'interim treatment'(5) ) &
        step(4) ::= false & step(5) ::= true .

```

% ----- interim treatment and general test requested

```

{ read_param( modified, 4 ) } &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & {W > 10} &
  student : 'interim treatment'(4) ::= true &
  student : 'general test'(4) ::= false

```

==>

```

select ( 'specific test'('csf exam', 5 ), 'contact specialist'(5), 'rehydration oral'(5),
        'specific test'(stool, 5 ), antibiotic(5), 'rehydration intravenous'(5),
        'specific test'('blood culture', 5) ) &
        step(4) ::= false & step(5) ::= true .

```

```

% -----Modifications 5
% % % % % { W =< 10 } % % % % %

% ----- oral rehydration requested (specific test done)
step(5) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W =< 10 } &
  student : 'rehydration oral'(5) ::= true &
    { existing_metafact( student, 'specific test'( stool, S), true ) } &
    { S < 5 } &
    { write_param( modified, 5 ) }
==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
  visible_symptoms(int, b1) <- not diarrhea(5) & not vomiting(5) &
  irritability(low, 5) ) .

% ----- specific test requested (oral rehydration done)
step(5) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W =< 10 } &
  student : 'specific test'( stool, 5) ::= true &
    { existing_metafact( student, 'rehydration oral'(R), true ) } &
    { R < 5 } &
    { write_param( modified, 5 ) }
==>
modify ( bacteria( int ) <-& specific_tests( stool ),
  specific_tests( stool ) <- blood( absent, 5 ) & 'bacterial culture'(positive, 5)
  & parasites( absent, 5 ) & viral( negative, 5 ) ) .

% ----- oral rehydration requested, but not specific test
step(5) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W =< 10 } &
  student : 'rehydration oral'(5) ::= true &
  student : 'specific test'( stool, 5) ::= false &
    { write_param( modified, 5 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
  visible_symptoms(int, b1) <- not diarrhea(5) & not vomiting(5) &
  irritability(low, 5) ) .

% ----- oral rehydration and specific test requested
step(5) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W =< 10 } &
  student : 'rehydration oral'(5) ::= true &
  student : 'specific test'( stool, 5) ::= true &
    { write_param( modified, 5 ) }

```

```

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & specific_tests( stool ),
        visible_symptoms(int, b1) <- not diarrhea(5) & not vomiting(5) &
        irritability(low, 5),
        specific_tests( stool ) <- blood( absent, 5 ) & 'bacterial culture'(positive, 5)
        & parasites( absent, 5 ) & viral( negative, 5 ) ) .

```

```

%%%%%%%%% {W > 10} %%%%%%%%%%
%%%%%%%%% [exam] [history & Hosp. & G.tests] [S.tests] [treatment]
%%%%%%%%%
%%%%%%%%% [exam & history] [G.tests & treatment] [Hosp. & S.test]
%%%%%%%%%

```

```

% ----- intravenous rehydration requested (specific test done)
step(5) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
  student : antibiotic(5) ::= true &
  student : 'rehydration intravenous'(5) ::= true &
    { existing_metafact( student, 'specific test'( stool, S), true ) } &
    { S < 5 } &
  student : 'specific test'( 'blood culture', U ) ::= true &
    { U < 5 } &
    { write_param( modified, 5 ) }

```

```

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
        visible_symptoms(int, b1) <- not diarrhea(5) & not vomiting(5) &
        irritability(low, 5) ) .

```

```

%%%%%%%%% [exam & history] [G.tests & treatment] [Hosp. & R A]
%%%%%%%%% [S.test] %%%%%%%%%%
%%%%%%%%% [exam & history] [G.tests & treatment] [Hosp.] [R A & S.test]
%%%%%%%%%
%%%%%%%%% [exam & history] [treatment] [G.tests & Hosp.] [R A & S.test]
%%%%%%%%%
%%%%%%%%% [exam] [history & Hosp. & G.tests] [treatment] [R A & S.test]
%%%%%%%%%
%%%%%%%%% [exam] [history & Hosp. & G.tests] [S.test] [treatment]
%%%%%%%%%

```

```

% ----- stool test requested (blood culture test done)
step(5) ::= true &
    sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
    student : 'specific test'( stool, 5 ) ::= true &
    student : antibiotic(T) ::= true &
    { T < 5 } &
    student : 'rehydration intravenous'(T) ::= true &
    { T < 5 } &
    student : 'specific test'( 'blood culture', U ) ::= true &
    { U < 5 } &
    { write_param( modified, 5 ) }
==>
modify ( bacteria( int ) <-& specific_tests( stool ),
    specific_tests( stool ) <- blood( absent, 5 ) & 'bacterial culture'(positive, 5)
    & parasites( absent, 5 ) & viral( negative, 5 ) ).

% ----- blood culture test requested (stool test done)
step(5) ::= true &
    sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
    student : 'specific test'( 'blood culture', 5 ) ::= true &
    student : antibiotic(T) ::= true &
    { T < 5 } &
    student : 'rehydration intravenous'(T) ::= true &
    { T < 5 } &
    student : 'specific test'( stool, S ) ::= true &
    { S < 5 } &
    { write_param( modified, 5 ) }

```



```

==>
modify ( bacteria( int ) <-& specific_tests( 'blood culture' ),
        specific_tests( 'blood culture' ) <- 'blood culture'( positive, 5 ) ).

%%%%%%%% [exam & history]      [G.tests & treatment] [Hosp.]      [R A]
%%%%%%%%
%%%%%%%% [exam & history]      [treatment]      [G.tests & Hosp.] [R A]
%%%%%%%%
%%%%%%%% [exam & history]      [G.tests]      [treatment & Hosp.] [R A]
%%%%%%%%
%%%%%%%% [exam & history]      [Hosp.]      [G.tests & treatment] [R A]
%%%%%%%%
%%%%%%%% [exam & history]      [Hosp. & G.tests] [treatment] [R A]
%%%%%%%%
%%%%%%%% [exam]      [history]      [Hosp. & G.tests & treatment] [R A]
%%%%%%%%
%%%%%%%% [exam]      [history & Hosp.] [G.tests & treatment] [R A]
%%%%%%%%
%%%%%%%% [exam]      [history & Hosp. & G.tests] [treatment] [R A]
%%%%%%%%
% ----- both specific tests requested
step(5) ::= true &
    sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
    student : 'specific test'( stool, 5 ) ::= true &
    student : 'specific test'( 'blood culture', 5 ) ::= true &
    student : 'rehydration intravenous'(4) ::= true &
    student : antibiotic(4) ::= true &
    { write_param( modified, 5 ) }

==>
modify ( bacteria( int ) <-& specific_tests( stool ) & specific_tests( 'blood culture' ),
        specific_tests( stool ) <- blood( absent, 5 ) & 'bacterial culture'(positive, 5)
        & parasites( absent, 5 ) & viral( negative, 5 ),
        specific_tests( 'blood culture' ) <- 'blood culture'( positive, 5 ) ).

% ----- stool test requested, but not blood culture
step(5) ::= true &
    sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
    student : 'specific test'( stool, 5 ) ::= true &
    student : 'specific test'( 'blood culture', 5 ) ::= false &
    student : 'rehydration intravenous'(4) ::= true &
    student : antibiotic(4) ::= true &
    { write_param( modified, 5 ) }

```

```

==>
modify ( bacteria( int ) <-& specific_tests( stool ),
        specific_tests( stool ) <- blood( absent, 5 ) & 'bacterial culture'(positive, 5)
        & parasites( absent, 5 ) & viral( negative, 5 ) ) .

% ----- blood culture test requested, but not stool test
step(5) ::= true &
    sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
    student : 'specific test'( 'blood culture', 5 ) ::= true &
    student : 'specific test'( stool, 5 ) ::= false &
    student : antibiotic(4) ::= true &
    student : 'rehydration intravenous'(4) ::= true &
    { write_param( modified, 5 ) }

==>
modify ( bacteria( int ) <-& specific_tests( 'blood culture' ),
        specific_tests( 'blood culture' ) <- 'blood culture'( positive, 5 ) ) .

% % % % % [exam & history] [G.tests & treatment] [Hosp.] [S.test]
% % % % %
% % % % % [exam & history] [Hosp.] [G.tests & treatment] [S.test]
% % % % %
% % % % % [exam & history] [Hosp. & G.tests] [treatment] [S.test]
% % % % %
% % % % % [exam & history] [Hosp. & treatment] [G.tests] [S.test]
% % % % %
% % % % % [exam] [history] [Hosp. & G.tests & treatment]
% % % % % [S.test]
% % % % % [exam] [history & Hosp.] [G.tests & treatment] [S.test]
% % % % %

% ----- intravenous rehydration requested (both specific tests done)
step(5) ::= true &
    sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
    student : antibiotic(5) ::= true &
    student : 'rehydration intravenous'(5) ::= true &
    { existing_metafact( student, 'specific test'( stool, 4), true ) } &
    { existing_metafact( student, 'specific test'( 'blood culture', 4), true ) } &
    { write_param( modified, 5 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
        visible_symptoms(int, b1) <- not diarrhea(5) & not vomiting(5) &
        irritability(low, 5) ) .

```

4

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS
STANDARD REFERENCE MATERIAL 1010a
(ANSI and ISO TEST CHART No. 2)

```

% ----- intravenous rehydration and blood culture test requested
% (only stool test done)
step(5) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : antibiotic(5) ::= true &
  student : 'rehydration intravenous'(5) ::= true &
  student : 'specific test'( 'blood culture', 5) ::= true &
    { existing_metafact( student, 'specific test'( stool, 4), true )} &
    { write_param( modified, 5 ) }
==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1)
  & specific_tests( 'blood culture' ),
  visible_symptoms(int, b1) <- not diarrhea(5) & not vomiting(5) &
  irritability(low, 5),
  specific_tests( 'blood culture' ) <- 'blood culture'(positive, 5) ).

% ----- intravenous rehydration requested (only stool test done)
% not blood culture test
step(5) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : antibiotic(5) ::= true &
  student : 'rehydration intravenous'(5) ::= true &
  student : 'specific test'( 'blood culture', 5) ::= false &
    { existing_metafact( student, 'specific test'( stool, 4), true )} &
    { write_param( modified, 5 ) }
==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
  visible_symptoms(int, b1) <- not diarrhea(5) & not vomiting(5) &
  irritability(low, 5) ).

% ----- intravenous rehydration and stool test requested
% (only blood culture test done)
step(5) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
  student : antibiotic(5) ::= true &
  student : 'rehydration intravenous'(5) ::= true &
  student : 'specific test'( stool, 5) ::= true &
    { existing_metafact( student, 'specific test'( 'blood culture', 4), true )} &
    { write_param( modified, 5 ) }
==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & specific_tests( stool ),
  visible_symptoms(int, b1) <- not diarrhea(5) & not vomiting(5) &
  irritability(low, 5),
  specific_tests( stool ) <- blood( absent, 5 ) & 'bacterial culture'(positive, 5)
  & parasites( absent, 5 ) & viral( negative, 5 ) ).

```

```
% ----- intravenous rehydration requested (only blood culture test done)
% not stool test
step(5) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
  student : antibiotic(5) ::= true &
  student : 'rehydration intravenous'(5) ::= true &
  student : 'specific test'( stool, 5) ::= false &
    { existing_metafact( student, 'specific test'( 'blood culture', 4), true )} &
    { write_param( modified, 5 ) }
```

```
==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
        visible_symptoms(int, b1) <- not diarrhea(5) & not vomiting(5) &
        irritability(low, 5) ) .
```

```
% % % % % [exam & history] [treatment] [Hosp.] [G.tests]
% % % % %
% % % % % [exam & history] [G.tests] [Hosp.] [treatment]
% % % % %
% % % % % [exam & history] [Hosp.] [treatment] [G.tests]
% % % % %
% % % % % [exam & history] [Hosp.] [G.tests] [treatment]
% % % % %
% % % % % [exam] [history] [G.tests & Hosp.] [treatment]
% % % % %
% % % % % [exam] [history] [Hosp.] [G.tests & treatment]
% % % % %
% % % % % [exam] [Hosp.] [history & G.tests] [treatment]
% % % % %
% % % % % [exam] [Hosp.] [history] [G.tests & treatment]
% % % % %
% % % % % [exam] [history & Hosp.] [G.tests] [treatment]
% % % % %
% % % % % [exam] [history & Hosp.] [treatment] [G.tests]
% % % % %
```

```
% ----- only antibiotic, intravenous rehydration requested
% none of specific tests done
```

```
step(5) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
  student : antibiotic(5) ::= true &
  student : 'rehydration intravenous'(5) ::= true &
  student : 'specific test'( stool, 5) ::= false &
  student : 'specific test'( 'blood culture', 5) ::= false &
    { write_param( modified, 5 ) }
```

```

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1),
        visible_symptoms(int, b1) <- not diarrhea(5) & not vomiting(5) &
        irritability(low, 5) ).

% ----- only antibiotic, intravenous rehydration and stool test requested
% no blood culture test done
step(5) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
  student : antibiotic(5) ::= true &
  student : 'rehydration intravenous'(5) ::= true &
  student : 'specific test'( stool, 5) ::= true &
  student : 'specific test'( 'blood culture', 5) ::= false &
  { write_param( modified, 5 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & specific_tests( stool ),
        visible_symptoms(int, b1) <- not diarrhea(5) & not vomiting(5) &
        irritability(low, 5),
        specific_tests( stool ) <- blood( absent, 5 ) & 'bacterial culture'(positive, 5)
        & parasites( absent, 5 ) & viral( negative, 5 ) ).

% ----- only antibiotic, intravenous rehydration and blood culture test requested
% no stool test done
step(5) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
  student : antibiotic(5) ::= true &
  student : 'rehydration intravenous'(5) ::= true &
  student : 'specific test'( 'blood culture', 5) ::= true &
  student : 'specific test'( stool, 5) ::= false &
  { write_param( modified, 5 ) }

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) &
        specific_tests( 'blood culture' ),
        visible_symptoms(int, b1) <- not diarrhea(5) & not vomiting(5) &
        irritability(low, 5),
        specific_tests( 'blood culture' ) <- 'blood culture'(positive, 5) ).

% ----- antibiotic and intravenous rehydration and both specific tests requested
% no stool test done
step(5) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
  student : antibiotic(5) ::= true &
  student : 'rehydration intravenous'(5) ::= true &
  student : 'specific test'( 'blood culture', 5) ::= true &
  student : 'specific test'( stool, 5) ::= true &
  { write_param( modified, 5 ) }

```

```

==>
modify ( bacteria( int ) <-& visible_symptoms(int, b1) & specific_tests( stool ) &
        specific_tests( 'blood culture' ),
        visible_symptoms(int, b1) <- not diarrhea(5) & not vomiting(5) &
        irritability(low, 5),
        specific_tests( stool ) <- blood( absent, 5 ) & 'bacterial culture'(positive, 5)
        & parasites( absent, 5 ) & viral( negative, 5 ),
        specific_tests( 'blood culture' ) <- 'blood culture'(positive, 5) ) .

%----- Selections 6
%%%%%%%% { W =< 10 } %%%%%%%%%
% final step
{ read_param( modified, 5 ) } &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W =< 10 } &
  { existing_metafact( student, 'rehydration oral'(R), true ) } &
  { R < 6 } &
  { existing_metafact( student, 'specific test'( stool, S), true ) } &
  { S < 6 }

==>
select ( 'virus of intestinal tract'(6), 'bacterial infection of intestinal tract'(6),
        'virus of neurological tract'(6) ) &
        step(5) ::= false & step(6) ::= true .

%%%%%%%% [exam]          [history]          [treatment]          [G. tests]          [Oral Reh]
%%%%%%%%
%%%%%%%% [exam]          [history]          [G. tests]          [treatment]          [Oral Reh]
%%%%%%%%
%%%%%%%% [history]        [exam]          [treatment]          [G. tests]          [Oral Reh] %%%
%%%%%%%% [history]        [exam]          [G. tests]          [treatment]          [Oral Reh] %%%
% ----- only oral rehydration requested, no specific test
{ read_param( modified, 5 ) } &
  student : 'rehydration oral'(5) ::= true &
  { \+ existing_metafact( student, 'specific test'( stool, _ ), true ) }

==>
select ( 'specific test'( stool, 6 ), 'specific test'('csf exam', 6 ),
        'specific test'( 'blood culture', 6 ), antibiotic(6),
        'rehydration intravenous'(6), hospitalization(6) ) &
        step(5) ::= false & step(6) ::= true .

```

```

%%% { W > 10 } %%%
% final step
{ read_param( modified, 5 ) &
  sick_infant : 'loss of weight'( W, 'per cent', _ ) ::= true & { W > 10 } &
  student : antibiotic( _ ) ::= true &
  student : 'rehydration intravenous'( _ ) ::= true &
    { existing_metafact( student, hospitalization( _ ), true ) } &
    { existing_metafact( student, 'specific test'( stool, _ ), true ) } &
    { existing_metafact( student, 'specific test'( 'blood culture', _ ), true ) }
==>
select ( 'virus of intestinal tract'(6), 'bacterial infection of intestinal tract'(6),
  'virus of neurological tract'(6) ) &
  step(5) ::= false & step(6) ::= true .

% everything done except stool test
{ read_param( modified, 5 ) &
  sick_infant : 'loss of weight'( W, 'per cent', _ ) ::= true & { W > 10 } &
  student : 'specific test'( stool, 5 ) ::= false &
  student : antibiotic( _ ) ::= true &
  student : 'rehydration intravenous'( _ ) ::= true &
    { existing_metafact( student, hospitalization( _ ), true ) } &
    { existing_metafact( student, 'specific test'( 'blood culture', _ ), true ) }
==>
select ( 'specific test'( 'csf exam', 6 ), 'contact specialist'(6), 'rehydration oral'(6),
  'specific test'( stool, 6 ) ) &
  step(5) ::= false & step(6) ::= true .

% everything done except blood culture test
{ read_param( modified, 5 ) &
  sick_infant : 'loss of weight'( W, 'per cent', _ ) ::= true & { W > 10 } &
  student : 'specific test'( 'blood culture', 5 ) ::= false &
  student : antibiotic( _ ) ::= true &
  student : 'rehydration intravenous'( _ ) ::= true &
    { existing_metafact( student, hospitalization( _ ), true ) } &
    { existing_metafact( student, 'specific test'( 'blood culture', _ ), true ) }
==>
select ( 'specific test'( 'csf exam', 6 ), 'contact specialist'(6), 'rehydration oral'(6),
  'specific test'( 'blood culture', 6 ) ) &
  step(5) ::= false & step(6) ::= true .

```



```

% everything done but none of specific tests done
{ read_param( modified, 5 ) &
  sick_infant : 'loss of weight'( W, 'per cent', _ ) ::= true & { W > 10 } &
  student : 'specific test'( stool, 5 ) ::= false &
  student : 'specific test'( 'blood culture', 5 ) ::= false &
  student : antibiotic( _ ) ::= true &
  student : 'rehydration intravenous'( _ ) ::= true &
    { existing_metafact( student, hospitalization( _ ), true ) }

==>
select ( 'specific test'( 'csf exam', 6 ), 'contact specialist'(6), 'rehydration oral'(6),
  'specific test'(stool, 6 ), 'specific test'( 'blood culture', 6 ) ) &
  step(5) ::= false & step(6) ::= true .

% -----Modifications 6
% % % % % { W =< 10 } % % % % %
% ----- specific test requested (oral rehydration done)
step(6) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W =< 10 } &
  student : 'specific test'( stool, 6 ) ::= true &
    { existing_metafact( student, 'rehydration oral'(R), true ) } &
    { R < 6 } &
    { write_param( modified, 6 ) }

==>
modify ( bacteria( int ) <-& specific_tests( stool ),
  specific_tests( stool ) <- blood( absent, 6 ) & 'bacterial culture'(positive, 6)
    & parasites( absent, 6 ) & viral( negative, 6 ) ) .

% % % % % { W > 10 } % % % % %
% ----- both specific tests requested
step(6) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent' , _ ) ::= true & { W > 10 } &
  student : 'specific test'( stool, 6 ) ::= true &
  student : 'specific test'( 'blood culture', 6 ) ::= true &
    { write_param( modified, 6 ) }

==>
modify ( bacteria( int ) <-& specific_tests( stool ) & specific_tests( 'blood culture' ),
  specific_tests( stool ) <- blood( absent, 6 ) & 'bacterial culture'(positive, 6)
    & parasites( absent, 6 ) & viral( negative, 6 ),
  specific_tests( 'blood culture' ) <- 'blood culture'( positive, 6 ) ) .

```

```

% ----- only stool test requested
step(6) ::= true &
    sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
    student : 'specific test'( stool, 6 ) ::= true &
    student : 'specific test'( 'blood culture', 6 ) ::= false &
    { write_param( modified, 6 ) }

==>
modify ( bacteria( int ) <-& specific_tests( stool ),
        specific_tests( stool ) <- blood( absent, 6 ) & 'bacterial culture'(positive, 6)
        & parasites( absent, 6 ) & viral( negative, 6 ) ) .

% -----only blood culture test requested
step(6) ::= true &
    sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
    student : 'specific test'( stool, 6 ) ::= true &
    student : 'specific test'( 'blood culture', 6 ) ::= false &
    { write_param( modified, 6 ) }

==>
modify ( bacteria( int ) <-& specific_tests( 'blood culture' ),
        specific_tests( 'blood culture' ) <- 'blood culture'( positive, 6 ) ) .

%----- Selections 7
%%%%%%%%% {W =< 10} %%%%%%%%%%
% ----- correct treatment and specific test done
{ read_param( modified, 6 ) } &
    sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W =< 10 } &
    student : 'specific test'( stool, U ) ::= true &
    { U =< 6 } &
    student : 'rehydration oral'(T) ::= true &
    { T =< 6 }

==>
select ( 'virus of intestinal tract'(7), 'bacterial infection of intestinal tract'(7),
        'virus of neurological tract'(7) ) &
    step(6) ::= false & step(7) ::= true .

%%%%%%%%% {W > 10} %%%%%%%%%%
% final step
{ read_param( modified, 6 ) } &
    sick_infant : 'loss of weight'( W, 'per cent', _ ) ::= true & { W > 10 } &
    student : antibiotic( ) ::= true &
    student : 'rehydration intravenous'( ) ::= true &
    { existing_metafact( student, hospitalization( ), true ) } &
    { existing_metafact( student, 'specific test'( stool, _ ), true ) } &
    { existing_metafact( student, 'specific test'( 'blood culture', _ ), true ) }

```

```

==>
select ( 'virus of intestinal tract'(7), 'bacterial infection of intestinal tract'(7),
        'virus of neurological tract'(7) ) &
        step(6) ::= false & step(7) ::= true .

% everything done except stool test
{ read_param( modified, 6 ) } &
  sick_infant : 'loss of weight'( W, 'per cent', _ ) ::= true & { W > 10 } &
  student : 'specific test'( stool, 6 ) ::= false &
  student : antibiotic( _ ) ::= true &
  student : 'rehydration intravenous'( _ ) ::= true &
    { existing_metafact( student, hospitalization( _ ), true ) } &
    { existing_metafact( student, 'specific test'( 'blood culture', _ ), true ) }
==>
select ( 'specific test'( 'csf exam', 7 ), 'contact specialist'(7), 'rehydration oral'(7),
        'specific test'(stool, 7) ) &
        step(6) ::= false & step(7) ::= true .

% everything done except blood culture test
{ read_param( modified, 6 ) } &
  sick_infant : 'loss of weight'( W, 'per cent', _ ) ::= true & { W > 10 } &
  student : 'specific test'( 'blood culture', 6 ) ::= false &
  student : antibiotic( _ ) ::= true &
  student : 'rehydration intravenous'( _ ) ::= true &
    { existing_metafact( student, hospitalization( _ ), true ) } &
    { existing_metafact( student, 'specific test'( 'blood culture', _ ), true ) }
==>
select ( 'specific test'( 'csf exam', 7 ), 'contact specialist'(7), 'rehydration oral'(7),
        'specific test'( 'blood culture', 7 ) ) &
        step(6) ::= false & step(7) ::= true .

% -----Modifications 7
% % % % % { W > 10 } % % % % %
% ----- stool test requested
step(7) ::= true &
  sick_infant : 'loss of weight'(W, 'per cent', _ ) ::= true & { W > 10 } &
  student : 'specific test'( stool, 7 ) ::= true &
  student : 'specific test'( 'blood culture', 6 ) ::= true &
    { write_param( modified, 7 ) }

==>
modify ( bacteria( int ) <-& specific_tests( stool ),
        specific_tests( stool ) <- blood( absent, 7 ) & 'bacterial culture'(positive, 7)
        & parasites( absent, 7 ) & viral( negative, 7 ) ) .

```

```

% ----- blood culture test requested
step(7) ::= true &
    sick_infant : 'loss of weight'(W, 'per cent', _) ::= true & { W > 10 } &
    student : 'specific test'( stool, 7 ) ::= true &
    student : 'specific test'( 'blood culture', 6 ) ::= true &
    { write_param( modified, 7 ) }
==>
modify ( bacteria( int ) <-& specific_tests( 'blood culture' ),
        specific_tests( 'blood culture' ) <- 'blood culture'( positive, 7 ) ).

%----- Selections 8
%%%%%%%%% { W > 10 } %%%%%%%%%%
% final step
{ read_param( modified, 7 ) } &
    sick_infant : 'loss of weight'( W, 'per cent', _ ) ::= true & { W > 10 } &
    student : antibiotic(_) ::= true &
    student : 'rehydration intravenous'(_) ::= true &
        { existing_metafact( student, hospitalization( ), true ) } &
        { existing_metafact( student, 'specific test'( stool, _ ), true ) } &
        { existing_metafact( student, 'specific test'( 'blood culture', _ ), true ) }
==>
select ( 'virus of intestinal tract'(8), 'bacterial infection of intestinal tract'(8),
        'virus of neurological tract'(8) ) &
    step(7) ::= false & step(8) ::= true .

%-----TERMINATION RULES
%%%%%%%%%
%%%%%%%%%
%%%%%%%%% existing_metafact( sick_infant, 'loss of weight'(W =<10) ) %%%%%%%%%%
%%%%%%%%%
%%%%%%%%%
% --- hospitalization requested, infant only sick
sick_infant : 'loss of weight'( W, 'per cent', _ ) ::= true & { W =< 10 } &
student : hospitalization(_) ::= true

==>
terminate ' :
    Condition of the patient does not
    warrant hospitalization.' .

% --- no general exam requested after selection 2
step(2) ::= true &
    sick_infant : 'loss of weight'( W, 'per cent', _ ) ::= true & { W =< 10 } &
    { \+ existing_metafact( student, 'general exam'(_), true ) }

```

```

==>
terminate ':
    You cannot proceed further.
    You must learn the proper management of the case.'.

% --- no history requested after selection 2
step(2) ::= true &
    sick_infant : 'loss of weight'( W, 'per cent', _ ) ::= true & { W =< 10 } &
    { \+ existing_metafact( student, 'patient history'(T), true ) }
==>
terminate ':
    You cannot proceed further.
    You must learn the proper management of the case.'.

% --- rehydration oral requested without general tests
student : 'rehydration oral'(T) ::= true &
    { \+ existing_metafact( student, 'general tests'(_), true ) }
==>
terminate ':
    You cannot proceed further.
    You must learn the proper management of the case.'.

% --- the request of general tests must be prior to rehydration oral
student : 'rehydration oral'(T) ::= true &
student : 'general tests'(T) ::= true
==>
terminate ':
    Rehydration oral cannot be requested
    without prior general tests.'.

% --- Incorrect specific test requested
sick_infant : 'loss of weight'( W, 'per cent', _ ) ::= true & { W =< 10 } &
student : 'specific test'( 'blood culture', _ ) ::= true
==>
terminate ':
    Incorrect specific test was selected.
    Please consult the specialist. ' '.

% --- antibiotic requested
sick_infant : 'loss of weight'( W, 'per cent', _ ) ::= true & { W =< 10 } &
student : antibiotic(_) ::= true
==>
terminate ':
    Incorrect treatment:
    antibiotic is not required.' .

```

```
% --- rehydration intravenous requested
% --- but the weight loss is less than 10 per cent
sick_infant : 'loss of weight'( W, 'per cent', _ ) ::= true & { W =< 10 } &
student : 'rehydration intravenous'(_) ::= true
```

```
==>
```

```
terminate ':
```

```
    Incorrect treatment:
    rehydration intravenous is not required.'.
```

```
% --- too long for diagnosis
```

```
step(5) ::= true &
```

```
    sick_infant : 'loss of weight'( W, 'per cent', _ ) ::= true & { W =< 10 } &
    { \+ existing_metafact( student, 'rehydration oral'(_), true ) }
```

```
==>
```

```
terminate ':
```

```
    The process is too long.
    The patient is suffering without treatment.
    You are advised to consult the specialist '.
```

```
%%%%%%%%%
```

```
%%%%%%%%%
```

```
%%%%%%%%% existing_metafact( sick_infant, 'loss of weight'(W > 10) ) %%%%%%%%%%
```

```
%%%%%%%%%
```

```
%%%%%%%%%
```

```
% --- general tests requested without patient history
```

```
student : 'general tests'(_) ::= true &
```

```
    { \+ existing_metafact( student, 'patient history'(_), true ) }
```

```
==>
```

```
terminate ':
```

```
    Without patient history,
    general tests cannot be requested.
    You must learn the proper management of the case.'.
```

```
% --- interim treatment requested without patient history
```

```
student : 'interim treatment'(2) ::= true &
```

```
student : hospitalization(2) ::= true &
```

```
    { \+ existing_metafact( student, 'patient history'(_), true ) }
```

```
==>
```

```
terminate ':
```

```
    Without patient history,
    interim treatment cannot be requested.
    You must learn the proper management of the case.'.
```

```
% --- no general tests requested before general exam
sick_infant : 'loss of weight'( W, 'per cent', _ ) ::= true & { W > 10 } &
student : 'general tests'(T) ::= true &
{ \+ existing_metafact( student, 'general exam'(_), true ) }
```

```
==>
```

```
terminate ':
```

General tests cannot proceed before the general exam is conducted.
You must learn the proper management of the case.'

```
% --- no general tests right after general exam at such condition
student : 'general exam'(1) ::= true &
sick_infant : 'loss of weight'( W, 'per cent', _ ) ::= true & { W > 10 } &
student : 'patient history'(2) ::= false &
student : 'general tests'(2) ::= true
```

```
==>
```

```
terminate ':
```

Under such condition,
next priority action is not general tests.
You must learn the proper management of the case.'

```
% --- rehydration intravenous requested without general tests
student : 'rehydration intravenous'(T) ::= true &
{ \+ existing_metafact( student, 'general tests'(_), true ) }
```

```
=>
```

```
terminate ':
```

You cannot proceed further.
You must learn the proper management of the case.'

```
% --- the request of general tests must be prior to rehydration intravenous
student : 'rehydration intravenous'(T) ::= true &
student : 'general tests'(T) ::= true
```

```
==>
```

```
terminate ':
```

Rehydration intravenous cannot be requested
prior to the selection of general tests.'

```
% --- the request of general tests must be prior to antibiotic
student : 'antibiotic'(T) ::= true &
student : 'general tests'(T) ::= true
```

```
==>
```

```
terminate ':
```

Antibiotic cannot be requested
prior to the selection of general tests.'

```

% --- rehydration oral requested
% --- but the weight loss is greater than 10 per cent
sick_infant : loss of weight'( W, 'per cent', _ ) ::= true & { W > 10 } &
student : 'rehydration oral'(_) ::= true
==>
terminate ':
    Incorrect treatment:
        oral rehydration is not sufficient.'.

% --- too long for diagnosis (without hospitalization)
step(3) ::= true &
    sick_infant : 'loss of weight'( W, 'per cent', _ ) ::= true & { W > 10 } &
student : hospitalization(3) ::= false
%      { \+ existing_metafact( student, hospitalization(_), true ) }
==>
terminate ':
    The process is too long.
    You are advised to consult the specialist '.

% --- too long for diagnosis (without rehydration intravenous)
step(5) ::= true &
    sick_infant : 'loss of weight'( W, 'per cent', _ ) ::= true & { W > 10 } &
    { \+ existing_metafact( student, 'rehydration intravenous'(_), true ) }

==>
terminate ':
    The process is too long.
    The patient is suffering without treatment.
    You are advised to consult the specialist '.

% --- too long for diagnosis (without antibiotic)
step(5) ::= true &
    sick_infant : 'loss of weight'( W, 'per cent', _ ) ::= true & { W > 10 } &
    { \+ existing_metafact( student, antibiotic(_), true ) }

==>
terminate ':
    The process is too long.
    The patient is suffering seriously without treatment.
    You are advised to consult the specialist '.

%%%%%%%%%                                %%%%%%%%%%
%%%%%%%%%    For both (W =<10) and (W>10)  %%%%%%%%%%
%%%%%%%%%                                %%%%%%%%%%
% --- hospitalization requested, infant only sick
student : hospitalization(1) ::= true

```



```

==>
terminate ' :
    Condition of the patient does not
    warrant hospitalization.' .

% --- contact specialist requested
student : 'contact specialist'(_) ::= true
==>
terminate ' :
    No reason to contact a specialist'.

% --- no general exam but interim treatment requested
student : 'interim treatment'(_) ::= true &
    { \+ existing_metafact( student, 'general exam'(_), true ) }
==>
terminate ' :
    No basis for interim treatment.
    General exam was not requested.' .

% --- interim treatment requested without patient history
student : 'interim treatment'(T) ::= true &
    { \+ existing_metafact( student, 'patient history'(_), true ) }

==>
terminate ' :
    You cannot proceed further.
    You must learn the proper management of the case.'.

% --- patient history and interim treatment
% --- cannot be requested simultaneously
student : 'patient history'(T) ::= true &
student : 'interim treatment'(T) ::= true
==>
terminate ' :
    Without patient history,
    interim treatment cannot be requested.
    You must learn the proper management of the case.'.

% --- too long for diagnosis
step(4) ::= true &
    { \+ existing_metafact( student, 'interim treatment'(_), true ) }
==>
terminate ' :
    The process is too long.
    The patient is suffering without treatment.
    You are advised to consult the specialist ' .

```

```
% --- Incorrect specific test requested
student : 'specific test'( 'csf exam', _ ) ::= true
==>
```

```
terminate ':
    Incorrect specific test was selected.
    Please consult the specialist. ' .
```

```
% --- Incorrect diagnosis
student : 'virus of intestinal tract'(_) ::= true
==>
```

```
terminate ':
    Incorrect diagnosis.
    Please consult the specialist. ' .
```

```
% --- Incorrect diagnosis
student : 'virus of neurological tract'(_) ::= true
```

```
==>
terminate ':
    Incorrect diagnosis.
    Please consult the specialist. ' .
```

```
% --- Correct diagnosis, but incorrect treatment
sick_infant : 'loss of weight'( W, 'per cent', _ ) ::= true & { W =< 10 } &
student : 'bacterial infection of intestinal tract'(_) ::= true &
student : antibiotic(_) ::= true &
    { \+ existing_metafact( student, 'rehydration oral'(_), true ) }
```

```
==>
terminate ':
    The correct diagnosis:
        bacterial infection of the intestinal tract.
    The interim treatment is incorrect. ' .
```

```
% --- Correct diagnosis and treatment
sick_infant : 'loss of weight'( W, 'per cent', _ ) ::= true & { W =< 10 } &
student : 'bacterial infection of intestinal tract'(_) ::= true &
student : 'rehydration oral'(_) ::= true
```

```
==>
terminate ':
    The correct diagnosis:
        Bacterial Infection of the Intestinal Tract.
    The interim treatment:
        Oral Rehydration.
    Congratulations' .
```

```

% --- Correct diagnosis and treatment
sick_infant : 'loss of weight'( W, 'per cent', _ ) ::= true & { W > 10 } &
student : 'bacterial infection of intestinal tract'(_) ::= true &
student : antibiotic(_) ::= true &
student : 'rehydration intravenous'(_) ::= true &
student : hospitalization(_) ::= true
==>
terminate ':
  The correct diagnosis:
    Bacterial Infection of the Intestinal Tract.
  The correct action:
    Patient was sent to hospital.
  The interim treatment:
    Intravenous Rehydration.
  Congratulations'.

```

All Possible Paths of Case Management for a Viral Intestinal Infection

Appendix O Possible Paths of Case Management for a Viral Intestinal Infection

The following scenarios show all possible paths of case management of an infant with a viral intestinal infection. These diagrams were used in testing the patient simulator to ensure that all possible paths were within the knowledge base. There are a total of twenty-one possible paths that could be taken in the management of a viral intestinal infection and each possible path is shown below.

All Possible Paths of Case Management for a Bacterial Neurological Infection

Appendix P

Possible Paths of Case Management for a Bacterial Neurological Infection

The following scenarios represent all possible paths of case management of a sick infant with a bacterial neurological infection. There are a total of thirty-seven possible paths that can be taken in the management of a bacterial neurological infection and each case is shown below.

* correct diagnosis with two correct treatments and contact neurologist

** correct diagnosis with one of two correct treatments and contact neurologist

* correct diagnosis with two correct treatments and contact neurologist

** correct diagnosis with one of two correct treatments and contact neurologist

* correct diagnosis with two correct treatments and contact neurologist

** correct diagnosis with one of two correct treatments and contact neurologist

* correct diagnosis with two correct treatments and contact neurologist

** correct diagnosis with one of two correct treatments and contact neurologist

* correct diagnosis with two correct treatments and contact neurologist

** correct diagnosis with one of two correct treatments and contact neurologist

* correct diagnosis with two correct treatments and contact neurologist

** correct diagnosis with one of two correct treatments and contact neurologist

* correct diagnosis with two correct treatments and contact neurologist

** correct diagnosis with one of two correct treatments and contact neurologist

* correct diagnosis with two correct treatments and contact neurologist

** correct diagnosis with one of two correct treatments and contact neurologist

* correct diagnosis with two correct treatments and contact neurologist

** correct diagnosis with one of two correct treatments and contact neurologist

* correct diagnosis with two correct treatments and contact neurologist

** correct diagnosis with one of two correct treatments and contact neurologist

All Possible Paths of Case Management for a Bacterial Intestinal Infection

Appendix Q

All Possible Paths of Case Management for a Bacterial Intestinal Infection

There are a total of 380 possible paths that can be taken in management of the bacterial intestinal infection as is shown below. Due to a lack of space, short forms are provided for each step in case management.

$W \leq 10$

W > 10

GE : general exam
PH : patient history
GT : general test
IT : interim treatment
H : hospitalization
T : antibiotic and
intravenous
rehydration
S1 : stool test
S2 : blood culture test
B : bacterial infection
of intestinal tract

**Screen Snapshots of Case Management of a Bacterial Neurological
Infection**

Appendix R

Screen Snapshots of Case Management of a Bacterial Neurological Infection

This appendix shows screen snapshots of a typical case management scenario for a bacterial neurological infection. The student is presented with the initial representation and based on the symptoms, makes the first selection of patient history and general exam.

i. Initial Representation and Selection 1

Options: Treating

Presenting your findings Save evidence

Sick Infant

- no chronic infections(1)
- no previous treatment(1)
- no prothetical(1)
- refusal to eat(0)
- vomiting(0)
- age(13 months,1)
- behaviour(abnormal,1)
- blood pressure(high,1)
- bowel movement(normal,1)
- diets change,1)
- family/no similar symptoms,1)
- fever(38,1)
- fontanelle(tight,1)
- head state(increased,1)
- irritability(neutral,0)
- length of symptoms(3 hours,1)
- loss of weight(0 per cent,1)
- pulse(high,1)
- pupils(equal,1)
- skin(normal,1)

Student

- true general exam(1)
- patient history(1)
- false contact specialist(1)
- hospitalization(1)

Select actions you want to perform:

- hospitalization(2)
- ☒ general tests(2)
- ☒ interim treatment(2)

Select
Close

Treatment

true score(0)

step(1)

false step(0)

ii. Modification 1 and Selection 2

As can be seen in the screen snapshot above, the results of the general exam are displayed in the left window as well as the symptoms. The student selects general tests and an interim treatment from the actions box.

iii. Modification 2 and Selection 3

A new representation of the sick infant emerges as the results of the general tests are displayed. The third selection involves choosing intravenous rehydration and antibiotics as the interim treatment and a C.s.f. exam as the specific test.

Options: Breeding Control	
Have you changed the current situation?	
<p>Sign infant</p> <p>fontanelle anterior symptoms, 1) fontanelle(tight, 1) fontanelle(tight, 1) head size(increased, 1) irritability(neutral, 3) motoric(elevated, 2) length of symptoms(5 hours, 1) loss of weight(per cent, 1) neutrophils(increase, 3) protein(increase, 2) pulse(high, 1) pulse(normal, 1) red cell(normal, 2) skin(normal, 1) sugar(normal, 2) white cell(25000, 2)</p> <p>false: diarrhoea(3) dry mouth(3) vomiting(3)</p>	<p>Student</p> <p>true interim treatment(2) general exam(1) patient history(1) rehydration intravenous(3) antibiotic(3) specific antibiotic exam, 3) general test(2)</p> <p>false contact antibiotic(1) rehydration(1) contact antibiotic(2) rehydration(2) rehydration oral(3) rehydration(3) specific antibiotic(3) specific antibiotic(3) contact antibiotic(3)</p>
<p>Environment</p> <p>true: score(0) step(3)</p> <p>false: step(0) step(1) step(2)</p>	

iv. Modification 3 and Selection 4

After the third modification, the results of the C.s.f. exam are displayed. It is also evident that the interim treatment has alleviated the infant's symptoms as the fontanel and head size are normal.

Options: Testing

Pressing your response will save progress

See patient	Student
familiar similar symptoms, 1) fever(38, 1) rashes(not light, 1) head aches(increased, 1) irritability(neutral, 3) notanosisfowled, 2) length of symptoms(3 hours, 1) loss of weight(0 per cent, 1) neutrophils(increase, 3) proteins(increase, 2) platelets(1) pus(not normal, 1) red cells(normal, 2) eosinophils, 1) sugar(normal, 2) white cells(25000, 2) false (normal, 3) dry mouth(3) vomiting(3)	true interim treatment(2) general exam(1) patient history(1) respiratory interventions(3) antibiotics(3) (1) (2) (3) (3) (3)

Select actions you want to perform:

order of inspection track(4)

☒ bacterial infection of neurological system(4)

☒ contact neurologist(4)

Select Close

True score(0)
step(3)

False step(0)
step(1)
step(2)

v. Modification 4 and Selection 5

At this point the student can make the diagnosis which is a bacterial neurological infection.

Options Tracking Control	
This is the end of this simulation	
<p>Step: infant</p> <p>loss of weight(0 per cent, 1) neutrophils(increase, 3) protein(increase, 2) pulse(high, 1) appt(normal, 1) red cell(normal, 2) skin(normal, 1) superficial, 2) white cell(\$5000, 2)</p> <p>false diarrhoea(3) dry mouth(3) vomiting(3)</p> <p>Terminated because of The correct diagnosis: bacterial infection of the neurological system The interim treatments: intravenous respiration, antibiotic, and contact neurologist Congratulations!</p>	<p>Step: adult</p> <p>general exam(1) patient history(1) respiration intravenous(3) antibiotic(3) bacterial infection of neurological system(4) contact neurologist(4) specific test(csf exam, 3) general test(2)</p> <p>false contact specialist(1) neurologist(1) contact specialist(2) neurologist(2) respiration drug(3) neurologist(3) specific test(stupor, 3) specific test(stupor, 3) contact specialist(3) virus of intestinal tract(4) parents of intestinal tract(4)</p>
Environment	
<p>step(4)</p> <p>false step(0) step(1) step(2) step(3)</p>	

vi. Modification 5 and Termination

The final modification results in a termination of the case as the diagnosis and interim treatment were correct.

Screen Snapshots of Case Management of a Bacterial Intestinal Infection

Appendix S

Screen Snapshots of Case Management of a Bacterial Intestinal Infection

This appendix shows screen snapshots of a typical case management scenario for a bacterial intestinal infection. The student is presented with the initial representation and based on the symptoms, makes the first selection of patient history and general exam.

i. Initial Representation and Selection 1

ii. Modification 1 and Selection 2

As can be seen in the screen snapshot above, the results of the general exam are displayed in the left window as are as the symptoms. The student selects general tests and an interim treatment from the actions box.

iii. Modification 2 and Selection 3

A new representation of the sick infant emerges as the results of the general tests are displayed. Third selection involves choosing: oral rehydration as the interim treatment and a stool test as the specific test if weight loss is less than or equal to 10%, and intravenous rehydration and hospitalization as the interim treatment and a stool test as the specific test if weight loss is >10%.

iv. Modification 3 and Selection 4

After the third modification, the results of the stool test are displayed. It is also evident that the interim treatment has alleviated the infant's symptoms as the diarrhea and the vomiting have disappeared. At this point the student can make the diagnosis which is a bacterial intestinal infection.

v. Modification 4 and Termination

The final modification results in the termination of the case as the diagnosis and interim treatment were correct.

**Screen Snapshots of a Terminated Case of a Bacterial Neurological
Infection**

Appendix T

Screen Snapshots of a Terminated Case of a Bacterial Neurological Infection

The following screen snapshots show the termination of a bacterial neurological case. The student has managed the case incorrectly, specifically, the student has chosen the incorrect specific test. The student selects general exam and patient history after observing the visible symptoms.

I. Initial Representation and Selection 1

Options: Testing

Pressing your buttons gives advice

Sick Infant	Student
no chronic infection(1) no previous treatment(1) no prothetical(1) refusal to eat(0) vomiting(0) age(13 months,1) behavior(febnormal,1) blood pressure(normal,1) bowel movement(normal,1) dieting change,1) family no similar symptoms,1) fever(20,1) fontanel(slight,1) head circumference,1) irritability(normal,0) length of symptoms(5 hours,1) loss of weight(0 per cent,1) pulse(normal,1) pupils(equal,1) skin(normal,1)	true general exam(1) patient history(1) false contact associated(1) hospitalization(1)

Select actions you want to perform:

hospitalization(2)
☒ general tests(2)
☒ interim treatment(2)

Select Close

Examination
true score(0) stop(1) false stop(0)

ii. Modification 1 and Selection 2

The results of the patient's history and the general exam are shown. The student selects general tests and an interim treatment.

iii. Modification 2 and Selection 3

The results of the general tests are shown and the student is asked to select an interim treatment. The student selects intravenous rehydration and antibiotics as well as a stool test for the specific test.

Options Tracking Control	
This is the end of this simulation	
Sick Infant	Student
call ambulance(2) diet/no change, 1) family/no similar symptoms, 1) fever(30, 1) fontanel(tight, 1) head size/increased, 1) irritability(normal, 0) stool/elevated, 2) length of symptoms(5 hours, 1) loss of weight(0 per cent, 1) protein(increased, 2) pulse/high, 1) pupil(equal, 1) red cell/normal, 2) urine(normal, 1) weight/normal, 2) white cell(25000, 2)	true interim treatment(2) general exam(1) patient history(1) specific test(stool, 3) general test(2) rehydration intravenous(3) antibiotic(3)
Terminated because of This is the incorrect specific test Please consult the specialist	
Environment	
true score(0) step(3)	
false step(0) step(1) step(2)	

iv. Modification 3 and Termination

The results of the stool test are not shown as the student has selected the incorrect specific test. The case is terminated.

**Screen Snapshots of a Terminated Case of a Bacterial Neurological
Infection**

Appendix U

Screen Snapshots of a Terminated Case of a Bacterial Intestinal Infection

The following screen snapshots show the termination of a bacterial intestinal case. The student has managed the case incorrectly, specifically, the student has chosen to contact a specialist which is not necessary.

i. Initial Representation and Selection 1

The student selects general exam and patient history after observing the visible symptoms.

ii. Modification 1 and Selection 2

The results of the patient's history and the general exam are shown. The student selects general tests and an interim treatment.

Options Testing Control	
Time to the end of this simulation	
Sick Infant	Student
no previous treatment bowel movement(normal) diarrhea(0) stooling change) dry nappies(1) family(no similar symptoms) refusal to eat(0) vomiting(0) age(13 months,1) behaviour(normal,1) blood pressure(low,1) fever(38,1) fontanelles,1) head circumference,1) irritability(normal,0) skin(tough,1) skin(normal,1) loss of weight(17, per cent,1) Terminated because of no reason to contact a specialist	true patient history(1) contact specialist(2) general exam(1) false contact specialist(1) hospitalization(1) intensive treatment(2) hospitalization(2) general test(2)
End Treatment	
true step(2) false step(0) step(1)	

iv. Modification 3 and Termination

The results of the general tests are not shown as the student has incorrectly chosen to contact the specialist which results in a termination of the case.

Patient Simulator Study Background

Appendix V

Patient Simulator Study Background

Study Purpose

The purpose of the study is to develop and test a patient simulator. The simulator was created to test the diagnostic and treatment skills of medical students.

Scope

The patient simulator is a prototype at this point in time. The simulator begins by presenting a list of symptoms at which point the user begins case management. The user will be presented with a list of options after each stage and will at some point in time be able to choose from: general exam, general tests, specific tests, interim treatment, and then make a diagnosis.

Study Completion

The completed prototype within the scope of this study will contain three infection types: a viral intestinal infection, a bacterial intestinal infection, and a bacterial neurological infection.

Contacts

Your assistance and feedback are very important in further developing the prototype, so please comment freely throughout the testing session. If you have any further questions or comments, feel free to contact me, Siobhan MacDonald, at 788-2600 Ext. 2397.

Thank you again for your help!

Questionnaire

Appendix W Questionnaire

Please evaluate the patient simulator on each of the following dimensions:

1) Is the screen set-up:

1	2	3	4	5
VERY POOR				VERY GOOD

Do you have any comments/suggestions?

2) Is the simulator speed:

1	2	3	4	5
VERY POOR				VERY GOOD

Do you have any comments/suggestions?

3) How representative of a diagnostic and treatment scenario is this patient simulator?

1	2	3	4	5
NOT REPRESENTATIVE				HIGHLY REPRESENTATIVE

4) Please indicate the extent to which you believe the patient simulator once completed, could help you test your diagnostic and treatment skills?

1	2	3	4	5
TO A SMALL EXTENT				TO A GREAT EXTENT

Do you have any comments/suggestions?

- 5) Do you feel that your diagnostic and treatment skills are tested adequately in your undergraduate medical program? Please comment.

- 6) In what year(s) do you feel that the patient simulator would be most useful for testing a student's diagnostic and treatment skills?

- a) first year
- b) second year
- c) third year
- d) fourth year
- e) any combination of the above, specify _____

- 7) Would you recommend this patient simulator to others as a way of testing one's diagnostic and treatment skills? Please comment.

YES NO

- 8) What faculty are you currently in?

- a) Medicine
- b) Arts
- c) Social Sciences
- d) Science
- e) Other _____

- 9) How many years of computer experience do you have?

- a) Less than one year
- b) 1-2 years
- c) 2-3 years
- d) Greater than 3 years

10) What year are you in?

- a) first
- b) second
- c) third
- d) fourth
- e) graduate
- f) post graduate
- g) other _____

11) If you are in medicine, what is your area of specialization?

12) What age range are you in?

- a) 15-19
- b) 20-24
- c) 25-29
- d) 30-35
- e) 36+

Demographic Profile of Users

Appendix X Demographic Profile Of Users

USER	AGE	SEX	STUDENT	MAJOR	YEARS OF COMPUTER EXPERIENCE
Version # 1					
1	28	F	YES	BUSINESS	3
2	33	F	YES	BUSINESS	6
3	24	M	YES	PSYCHOLOGY	2
4	30	M	YES	BIOLOGY	0
Version # 2					
5	24	F	YES	MEDICINE - X-RAY	3
6	26	F	YES	MEDICINE- PEDIATRICS	1
7	22	M	YES	PHARMACOLOGY	4
8	23	F	YES	BIOLOGY	2
Version # 3					
9	27	M	YES	MEDICINE- RADIOLOGY	2
10	25	M	YES	MEDICINE- INTERNAL	0
11	30	F	YES	NURSING- SURGERY	3
12	24	M	YES	MEDICINE- GERIATRICS	1

Table of Quantitative Results

Appendix Y
Table of Quantitative Results

STUDENTS

	1	2	3	4	5	6	7	8	9	10	11	12
S1												
A	3	1	3	4	2	7	1	2	3	5	N/A	4
B	3	1	3	4	2	7	1	2	4	3	N/A	3
C	2	2	2	3	1	9	1	3	2	3	N/A	3
D	2	2	3	3	1	9	1	3	0	5	N/A	1
AV	2.5	1.5	2.75	3.5	1.5	N/A	1	N/A	2.25	N/A	N/A	N/A
S2												
E	3	2	3	4	2	7	1	1	2	4	6	2
F	3	1	3	4	1	7	1	1	1.5	4	2	2
G	4	3	3	4	2	2	1	1	0	4	1	2
H	3	3	4	5	2	12	1	1	1	4	7	2
AV	3.25	2.25	3.25	4.25	1.75	N/A	1	N/A	1.12	N/A	N/A	N/A
S3												
I	3	3	3	4	2	7	1	1	4	2	8	2
J	4	3	4	5	2	9	1	4	3	2	N/A	3
K	4	3.5	4	5	2	7	1	4	2.5	3	N/A	3
L	4	3	5	4	1	7	1	4	6	4	N/A	2
AV	3.75	3.12	4.0	4.5	1.75	N/A	1	N/A	3.87	N/A	N/A	N/A
AV	3.16	2.16	3.13	4.16	1.66	N/A	1	N/A	1.81	N/A	N/A	N/A

The horizontal axis represents the questions asked in the questionnaire (Questions 1 to 12). The vertical axis (students) represents each student tested (letters A to L).

Summary of Quantitative Results

Appendix Z Summary of Quantitative Results

The following is a summary of the quantitative results.

- 1) Is the screen set-up:

1	2	3	4	5
VERY POOR				VERY GOOD

The screen set-up rating moved from 2.5 in the first session (poor to average), to 3.25 in the second session (average), to 3.75 in the third session (good).

- 2) Is the simulator speed:

1	2	3	4	5
VERY POOR				VERY GOOD

The simulator speed rating moved from 1.25 in the first session (very poor) to 2.25 in the second session (poor), to 3.12 in the third session (average).

- 3) How representative of a diagnostic and treatment scenario is this patient simulator?

1	2	3	4	5
NOT REPRESENTATIVE				HIGHLY REPRESENTATIVE

The representative of the patient simulator of a diagnostic and treatment scenario moved from 2.75 in the first session (average) to 3.25 in the second session (average) to 4 in the third session (good).

- 4) Please indicate the extent to which you believe the patient simulator once completed, could help you test your diagnostic and treatment skills?

1	2	3	4	5
TO A SMALL EXTENT				TO A GREAT EXTENT

The helpfulness of the patient simulator in testing a student's diagnostic and treatment skills received a rating of 3.5 in the first session (from to an average extent to a great extent), to 4.25 in the second session (to a great extent), to 4.5 in the third session (to a very great extent).

- 5) Do you feel that your diagnostic and treatment skills are tested adequately in your undergraduate medical program? Please comment.

The adequacy of the testing of a medical student's diagnostic and treatment skills in their undergraduate medical program received a 1.5 in the first testing session (both adequate and inadequate), 1.75 in the second testing session (not adequate), and 1.75 in the third testing session (not adequate).

- 6) In what year(s) do you feel that the patient simulator would be most useful for testing a student's diagnostic and treatment skills?

- a) first year
- b) second year
- c) third year
- d) fourth year
- e) any combination of the above, specify _____

Fifty eight percent of the students in all sessions felt that the patient simulator would be most useful in the third and fourth years of medical school, twenty five percent felt that the patient simulator would be most useful in the second, third and fourth years of medical school, while eight percent felt it would be most useful in all years and the final eight percent felt that it would be most useful in all years of study.

- 7) Would you recommend this patient simulator to others as a way of testing one's diagnostic and treatment skills? Please comment.

YES

NO

All students in each session stated that they would recommend the patient simulator as a way of testing one's diagnostic and treatment skills.

- 8) What faculty are you currently in?

- a) Medicine
- b) Arts
- c) Social Sciences
- d) Science
- e) Other _____

Forty one percent of the students were in medicine, seventeen percent were in arts, seventeen percent were in the social sciences and thirty four percent were in the pure and applied sciences.

- 9) How many years of computer experience do you have?

- a) Less than one year
- b) 1-2 years
- c) 2-3 years
- d) Greater than 3 years

The average amount of computer experience for all students tested was one and a half years.

10) What year are you in?

- a) first
- b) second
- c) third
- d) fourth
- e) graduate
- f) post graduate
- g) other _____

Twenty percent of the students were in second year, twenty-five percent were in third year, forty percent were in fourth year, and fifteen percent were in graduate school.

11) If you are in medicine, what is your area of specialization?

The students who were in medicine specialized in the following areas: musculoskeletal, the respiratory system, the cardiovascular system, the nervous system, and the neurological system.

12) What age range are you in?

- a) 15-19
- b) 20-24
- c) 25-29
- d) 30-35
- e) 36+

Nine percent of the students tested were from fifteen to nineteen years old, fifty percent were from twenty to twenty-four, thirty-three were from twenty-five to twenty-nine, and eight percent were from thirty to thirty-five years old.

Coding Breakdown

Appendix AA

Coding Breakdown

The coding breakdown uses numbers to breakdown the quantitative questions (Questions 1, 2, 3, 4, 5, and 7). Letters are used to breakdown the qualitative questions (Questions 6, 8, 9, 10, 11, and 12).

QUESTION

1.	1)	VERY POOR
	2)	POOR
	3)	AVERAGE
	4)	GOOD
	5)	VERY GOOD
2.	1)	VERY POOR
	2)	POOR
	3)	AVERAGE
	4)	GOOD
	5)	VERY GOOD
3.	1)	NOT REPRESENTATIVE
	2)	SOMEWHAT REPRESENTATIVE
	3)	REPRESENTATIVE
	4)	HIGHLY REPRESENTATIVE
	5)	COMPLETELY REPRESENTATIVE
4.	1)	TO A VERY SMALL EXTENT
	2)	TO A SMALL EXTENT
	3)	TO AN AVERAGE EXTENT
	4)	TO A LARGE EXTENT
	5)	TO A VERY LARGE EXTENT
5.	1)	YES
	2)	NO

6. a) FIRST YEAR
 b) SECOND YEAR
 c) THIRD YEAR
 d) FOURTH YEAR
 e) FIRST AND SECOND YEAR
 f) SECOND AND THIRD YEAR
 g) THIRD AND FOURTH YEAR
 h) FIRST, SECOND, THIRD YEAR
 i) SECOND, THIRD, FOURTH YEAR
 j) FIRST AND THIRD YEAR
 k) SECOND AND FOURTH YEAR
 l) ALL YEARS
7. 1) YES
 2) NO
8. a) MEDICINE
 b) ARTS
 c) SOCIAL SCIENCE
 d) SCIENCE
9. a) LESS THAN ONE YEAR
 b) 1-2 YEARS
 c) 2-3 YEARS
 d) GREATER THAN 3 YEARS
10. a) FIRST
 b) SECOND
 c) THIRD
 d) FOURTH
 e) GRADUATE
 f) POST GRADUATE

11. a) CARDIOVASCULAR
b) RESPIRATORY
c) IMMUNOLOGY
d) RENAL
e) HAEMATOLOGY
f) MUSCULOSKELETAL
g) NERVOUS SYSTEM
h) MIND
i) SENSES
j) GASTROINTESTINAL

12. a) 15-19
b) 20-24
c) 25-29
d) 30-35
e) 36+

Qualitative Results of Testing Sessions

Appendix AB

Qualitative Results of Testing Sessions

VERSION 1

Negoplan Version: Negoplan Version 1.1i
Knowledge Base: Medic.One
Case Tested: Viral Intestinal Infection
Test Date: April 26th, 1993

Comments and Suggestions:

- 1) Is it an infant or a child?
- 2) When I am asked if I have analyzed the current situation, no matter whether I choose yes or no I get the same result.
- 3) When I chose general exam and patient history, interim treatment and general tests, and rehydration intravenous and antibiotics I was caught in an endless loop.
- 4) When I chose patient history and general tests I was terminated. Why?
- 5) The computer is very slow.

Changes:

- 1) The title of the first window was changed to Sick Infant
- 2) This was not changed until Negoplan Version 2.1 at which time the student could select either yes or no and different actions would result.
- 3) & 4) A flowchart was drawn up showing all possible selections which allowed for a thorough testing of the knowledge base. This was done to prevent the patient simulator from looping. This also allowed for all termination cases to have explanations.
- 5) The speed of the computer was not changed until Negoplan Version 2.1 as it is a time consuming process to remove all redundancies from the knowledge base.

Researcher's Comments:

All of the graphical user interface changes were made. The only improvement which could not be made was to improve the speed of the computer. The first version was tested by non-medical students therefore the majority of comments pertain to the graphical user interface and the functional aspects of the patient simulator.

VERSION TWO

Negoplan Version: Negoplan Version 1.1k
Knowledge Base: Medic.Two
Date Tested: May 3rd, 1993
Case Tested: Viral Intestinal Infection

Comments and Suggestions:

- 1) What is the age of the patient?
- 2) If we choose the wrong interim treatment, why are we terminated? Isn't it more realistic that we can go back to the previous step?
- 3) In a realistic case management setting, it would take weeks to get a viral culture back. How is this time taken into account within the patient simulator?
- 4) What does forward chaining mean?
- 5) Instead of being given the results for the specific tests, we should be able to choose them ourselves.
- 6) The patient simulator is quite slow.
- 7) What happens if we take too long to make the diagnosis? Does the patient's condition worsen?

Changes:

- 1) The age of the patient was added to the results of the general exam.
- 2) It was decided that students would not be allowed to go back after an incorrect action was selected. As the patient simulator is operating as a testing instrument, in a test situation, one does not have the opportunity to change answers.
- 3) When a specific test is chosen that requires time before it is returned, the student is notified that the results of the test are pending.
- 4) The comment Forward chaining...have patience was changed to Processing your responses...have patience.
- 5) Options were set up to allow the student to choose the specific test which they want instead of being provided with the results of a specific test.

- 6) The structure of the knowledge base was modified somewhat to allow for more efficient operation of the patient simulator.
- 7) A termination rule was introduced whereby the case is terminated if the student takes longer than a specified period of time to make a diagnosis.

Researcher's Comments:

The second version of the patient simulator was tested entirely by medical students.

VERSION THREE

Negoplan Version: Negoplan Version 2.1
Knowledge Base: Medic.Three
Date Tested: May 15th, 1993
Case Tested: Bacterial Neurological Infection

Comments and Suggestions:

- 1) How do I know what stage I am at in case management?
- 2) Is the interim treatment for the bacterial neurological sufficient e.g. IV rehydration and antibiotics? Would a general practitioner be able to handle this case?
- 3) It is not clear that the environment window is actually the window where the scoring takes place. If I am testing myself, this should be more obvious.

Changes:

- 1) To indicate the stage at which a selection was made by the student, the step number is placed beside the case management action to provide the student with a time frame.
- 2) The diagnosis for the bacterial neurological case was changed to include consulting a specialist.
- 3) The title of the environment window was changed to the evaluation window.

Researcher's Comments:

At the conclusion of the testing session for version three of the patient simulator, the usability goals were reached. In addition, feedback from the students was quite positive and there were few suggestions for changes.

Screen Snapshots of Negoplan Version 1.1i

Appendix AC

Screen Snapshots of Negoplan Version 1.1i

The first version of the patient simulator ran with Negoplan Version 1.1i as the Negoplan version and Medic.One as the knowledge base. This version ran the viral intestinal case. The screen snapshots shown in this appendix show the shortest path to the diagnosis. The same scenario for Version Four of the patient simulator is described in detail in Section 5.3.2.3. The differences between each version is described in detail in Appendix AB.

i. Initial Representation and Selection 1

ii. Modification 1 and Selection 2

iii. Modification 2 and Selection 3

Navigation Select «go» to see the results of your actions

Sick Infant	Student
true	plot(no_change)
true	family(no_similar_symptoms)
true	fever(38)
true	fontanel(ok)
true	head_size(normal)
true	leukocytes(normal)
true	protein(normal)
true	pulse(normal)
true	red_cell(normal)
true	skin(normal)
true	sugar(positive)
true	white_cell(normal)
true	loss_of_weight(5_per_cent)
true	respiration oral
true	specific_loose
false	respiration intravenous
false	antibiotic
false	contact_specialist
false	selection

Entertainment

false score(30)
 false score(40)
 false score(70)
 false score(90)
 false stop(2)
 false score(100)

Navigation Quit

iv. Modification 3 and Selection 4

Navigation Processing your responses Save settings

Sick Infant	Student
true	general_exam(1)
true	patient_history(1)
true	internal_treatment(2)
true	general_test(2)
true	specific_test(3)
true	respiration oral
true	respiration intravenous(3)
true	antibiotic(3)
true	contact_specialist(3)

Entertainment

false score(30)
 false score(50)
 false score(70)
 false score(90)
 false stop(2)
 false score(100)

Select actions you want to perform:

☐ stress_of_pneumological_tract
☒ stress_of_intestinal_tract

Select Close

v. Modification 4 and Selection 5

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS
STANDARD REFERENCE MATERIAL 1010a
(ANSI and ISO TEST CHART No. 2)

vi. Modification 5 and Termination

Screen Snapshots of Negoplan Version 1.1k

Appendix AD

Screen Snapshots of Negoplan Version 1.1k

The second version of the patient simulator ran with Negoplan Version 1.1k as the Negoplan version and Medic.Two as the knowledge base. This version ran the viral intestinal case. The screen snapshots shown in this appendix show the shortest path to the diagnosis. The same scenario for Version Four of the patient simulator is described in detail in Section 5.3.2.3.

i. Initial Representation and Selection 1

ii. Modification 1 and Selection 2

iii. Modification 2 and Selection 3

reception Thu, 10/29/99 09:11

Do you want to see the results of your actions?

Sick child	Student
true	diets(no_change)
true	family(no_similar_symptoms)
true	fever(38.1)
true	fontanel(ok)
true	head_size(normal)
true	irritability(normal)
true	ketones(elevated)
true	proteins(absent)
true	pudding(increased)
true	red_cell(normal)
true	skin(normal)
true	sugar(absent)
true	white_cell(normal)
true	loss_of_weight(0.5_per_cent)
true	rehydration oral
true	specific_tests
false	rehydration_intravenous
false	antibiotic
false	selection

Environment

false	step(1)
false	score(20)
false	score(30)
false	score(50)
false	step(2)
false	score(70)

iv. Modification 3 and Selection 4

reception Thu, 10/29/99 09:11

Forward clipboard. Save patients

Sick child	Student
true	refused_to_eat
true	behavior(normal)
true	blood_in_urine(absent)
true	blood_pressure(low)
true	bowel_movement(normal)
true	cell_smear(normal)
true	diets(no_change)
true	family(no_similar_symptoms)
true	fever(37.9)
true	fontanel(ok)
true	head_size(normal)
true	ketones(elevated)
true	proteins(absent)
true	pudding(increased)
true	red_cell(normal)
true	skin(normal)
true	sugar(absent)
true	viral(positive)
true	white_cell(normal)
true	loss_of_weight(0.5_per_cent)

Select actions you want to perform:

- virus_of_neurological_tract
- ✓ virus_of_intestinal_tract

Sick child	Student
true	patient_history(1)
true	general_exam(1)
true	interim_treatment(2)
true	general_test(2)
true	specific_test(3)
true	rehydration_oral(3)
false	rehydration_intravenous(3)
false	antibiotic(3)
false	selection

Environment

false	step(1)
false	score(20)
false	score(30)
false	score(50)
false	step(2)
false	score(70)

v. Modification 4 and Selection 5

vi. Modification 5 and Termination

Screen Snapshots of Negoplan Version 2.1

Appendix AE

Screen Snapshots of Negoplan Version 2.1

The third version of the patient simulator ran with Negoplan Version 2.1 as the Negoplan version and Medic.Three as the knowledge base. This version ran the bacterial neurological infection. The screen snapshots shown in this appendix show the shortest path to the diagnosis. The same scenario for Version Four of the patient simulator is described in detail in Section 5.3.2.3.

i. Initial Representation and Selection 1

ii. Modification 1 and Selection 2

iii. Modification 2 and Selection 3

Options Tracking Control Tue, 10/20/2011 10:00 AM

Are you willing to change your goal tree?

Sick Infant	Student
head_size(normal) irritability(normal) ketones(elevated) proteins(absent) pulse(high) red_cell(normal) skin(normal) sugar(absent) white_cell(normal) loss_of_weight(0_per_cent) rehydration_oral specific_tests(stool) false rehydration_intravenous antibiotic specific_tests(urine) specific_tests(lumbar_puncture) specific_tests(csf_exam) contact_specialist selection	true general_exam(1) patient_history(1) internal_treatment(2) general_tests(2) rehydration_oral(3) false contact_specialist(1) hospitalization(1) contact_specialist(2) hospitalization(2) rehydration_intravenous(3) antibiotic(3) contact_specialist(3)

Environment

score(20)
score(30)
score(50)
score(70)
score(90)
step(2)

iv. Modification 3 and Selection 4

Options Tracking Tue, 10/20/2011 10:00 AM

Processing your response Save progress

Sick Infant	Student
blood_in_urine(absent) blood_pressure(low) bowel_movement(normal) cell_smear(normal) dieting_change family_no_similar_symptoms fever(37.0) fontanelle(ok) head_size(normal) ketones(elevated) parasites(absent) pulse(absent) proteins(absent) pulse(normal) red_cell(normal) skin(normal) sugar(absent) viral(positive) white_cell(normal) loss_of_weight(5_per_cent)	true general_exam(1) patient_history(1) internal_treatment(2) general_tests(2) rehydration_oral(3) false contact_specialist(1) hospitalization(1) contact_specialist(2) hospitalization(2) rehydration_intravenous(3) antibiotic(3) contact_specialist(3)

Select actions you want to perform:

virus_of_neurological_tract

✓ virus_of_intestinal_tract

Select Close

Environment

score(20)
score(30)
score(50)
score(70)
score(90)
step(2)

v. Modification 4 and Selection 5

vi. Modification 5 and Termination

Session Logs

Appendix AF

Session Logs

The session logs can be viewed on the enclosed diskette.

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Appendix AF can be viewed on a diskette available only at the Carleton
University Library.

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