Peitho:
a Tool to Support Critical Thinking

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Abstract

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A new generic model of the structure and process of critical thinking is proposed. This model is the basis for a software tool which permits the representation of a variety of specific models of critical thinking. The tool is an environment that supports the development and analysis of arguments; it also supports the teaching and learning of critical thinking skills. The usefulness of the program is established across a variety of critical thinking activities for a range of users from learner to expert in various domains of discourse. An expert evaluation by an instructor of argument supports the claims for possible educational use. Some features of the design are shown to have application in existing cooperative work systems.

Acknowledgments

First and foremost, Dr. Gary Boyd, my thesis supervisor. The best decision I ever made was to come to Concordia, to Educational Technology, after being inspired by Gary's presentation at a conference in 1987. An abiding concern for the human family infuses all his work and I'm honoured to have had his influence.

The other committee members, Dr. Richard Schmid and Dr. Steven Shaw. Four feet firmly on the ground. Good thing.

My family, Dee and Jessica. I don't think they suffered too much but that just shows how supportive and gracious they have been. They did get to live in Montréal for a year.

Mandie Aaron, a friend at all the right times.

Dr. Lance Odland, a philosopher who has become a friend.

And Dr. Douglas Goldsack, the dean who made me do it. I admit there were times when that seemed like the only reason.

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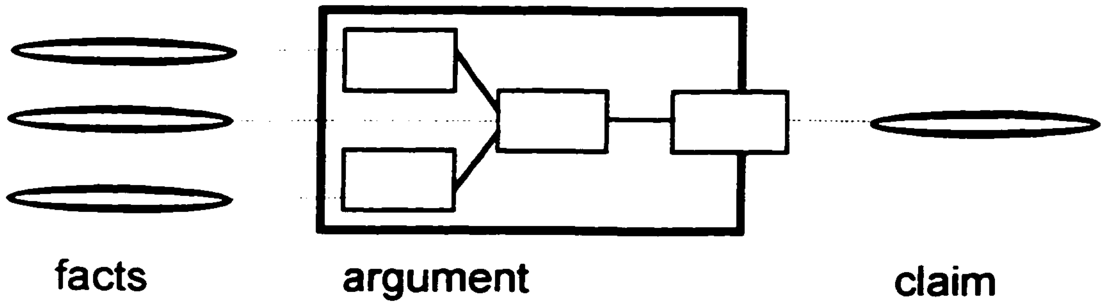
Glossary

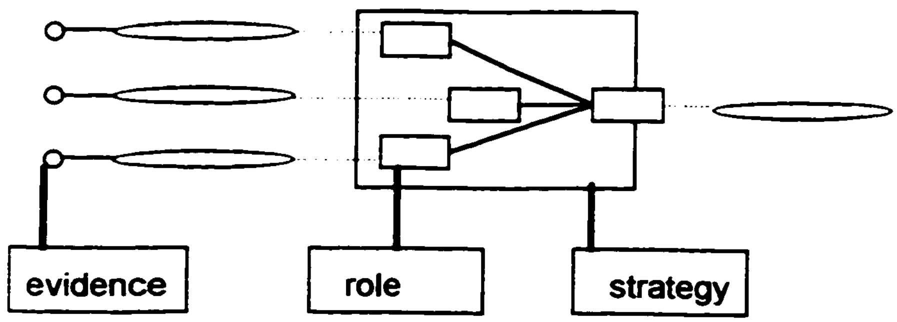
The following terms have been used with different meanings in many contexts concerning critical thinking and reasoning. They are used in this document with definitions related to the model and software under development. In most cases these definitions are compatible with general usage but the full implication of each term in this context is necessary to understand the text. Here brief and somewhat circular definitions are supplied. The terms are fully discussed in the description of the model in section 4.1.

- **Argument**: reasoning to develop a **claim** based on a (small) set of **facts**.
- **Chain of reasoning**: a set of related **arguments** which together establish a **major claim**.
- **Claim**: a **statement** which is not generally accepted but which is established through an **argument**.
- **Evidence**: the type of the external **support** offered to establish a **statement** as a **fact**.
- **Fact**: a **statement** which is assumed to be true within the context of an **argument**. A fact is established either by external **support** or by another **argument** of which it is the **claim**.
- **Major claim**: a **claim** which is established through a **chain of reasoning**. Typically, the major claim has significance outside the discourse and its establishment is the goal of the chain of reasoning.
- **Node**: one element of an **argument**. A **statement** must be associated with each node of an argument.

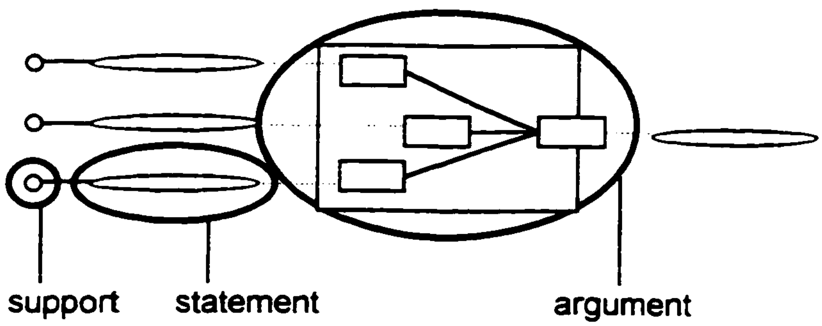
- **Role**: the type of a **node** in an **argument**. The role determines the requirements for the **statement** which is associated with the node. One node has the role of **claim** and the statement associated with it is the statement established by the argument.
- **Statement**: a unit of information from the domain of discourse. A statement may express a value, belief or actuality; it may be specific or general, accepted or contentious.
- **Strategy**: the type of an **argument**. Strategy specifies the **roles** of the **nodes** in the argument and the relations among them.
- **Support**: a reference external to the chain of reasoning which establishes a **statement** as a **fact**.

Figure 0.1: Terminology in Context





The types (templates) of the elements



The generic elements

1. Introduction

1.1 The Educational Problem and Issues

We often hear laments that students lack critical thinking skills. Sometimes, the concern is that learners are too slow to challenge and question knowledge presented to them; sometimes, the problem is an inability to construct a solid chain of reasoning.

The need for these skills only increases as information technologies evolve. We are exposed to more and more sophisticated and persuasive information sources; we are regularly confronted with once distant situations where we need to appreciate unfamiliar and conflicting customs; we face problems which will only yield to creative, multi-disciplinary solutions. Students must be ready to function effectively in situations where little can be assumed beyond a commitment to rationality.

1.1.1 Critical Thinking

Being a critical thinker means at least understanding the concepts of rational argumentation and applying the concepts in two complementary ways. One must be able to construct a reasoned argument in support of a claim he is committed to, and one must be able to understand and critically examine a reasoned argument presented by someone else.

Many educators have studied critical thinking and how it can be learned but few have investigated the potential of educational software in this regard. Programs which address topics where critical thinking is an important skill, such as creative writing software, typically avoid the argumentation issue or treat it superficially.

In contrast, there are many textbooks and other materials to guide anyone wanting to learn critical thinking. Most of these sources provide a piece-by-piece description of a rational argument and some tactics for constructing or critiquing one. Together, they form an extensive base of models which could be implemented in a program. Unfortunately, many of the models prove to be incomplete when they are tested under the rigorous conditions of software implementation and use.

The primary goal of this research project was to propose a new model of argumentation robust enough to serve as a basis for educational software development and test it in a program.

1.1.2 Interdisciplinary Communication

The two sides of critical thinking, the creation of persuasive chains of reasoning and the evaluation of the reasoning of others, imply quite correctly that reasoning is a personal but also a public activity, part of a conversation in some particular domain of discourse which determines the conventions.

The domain conventions underlie the discourse because they provide a common starting point for reasoning. When conversations breach domain boundaries, the shared starting point is lost and the parties must either establish some common ground on which to begin or be doomed to arguing at cross-purposes with their best hope being to agree to disagree. (Toulmin, Rieke and Janik, 1979) There is potential for this kind of problem in any multi-disciplinary or cross-cultural setting.

International organizations have recognized this situation and have developed activities which prepare their staffs for cross-cultural situations. (Klabbers, 1989) In these training activities, computer-based or not, there is also a tendency to treat critical thinking skills superficially.

A longer term goal of this investigation is to consider whether a model of discourse based on critical thinking in which the conventions of the various domains of discourse are describable could be used to improve these training materials.

1.2 Purpose of the Research Project

The focus of the research project is the creation of a model for the development of critical thinking software but some issues related to other research areas are examined along the way.

1.2.1 Major Purpose: Model and Software

The major purpose of this project is the development of a model of reasoning suitable for supporting and learning critical thinking and ultimately for enabling interdisciplinary discourse. The model must include both the product and the process of critical thinking. The product is a representation of a chain of reasoning that captures the organization and content of the arguments, including weaknesses and fallacies. The process is a methodology for assembling, organizing and evaluating the elements of this representation.

The model must succeed both as a representation of the activity of critical thinking and as a basis for teaching and learning critical thinking. It is developed and verified by designing software to implement the theory. The software is written to address the primary task of learning critical thinking. It is tested for this task but it also produces some insights concerning the long term goal of enabling interdisciplinary communication.

1.2.2 Secondary Purpose - Extension of Hyperintelligence Software Model

While there are few precedents in the educational field, the model of critical thinking proposed here is similar to those underlying a category of group work support tools called hyperintelligence systems. These programs, which facilitate group design and decision making for example, are also based on a structural model and a process for manipulating it. In this project, features of the model and the software address some of the issues identified in the literature. It is a secondary purpose of this project to investigate four novel features of the design as possible solutions to the problems with these tools.

1.3 Background

1.3.1 Rationality, Reasoning, Critical Thinking[1]

Classical rhetoric, the art of persuasion, was supported by three strategies: *pathos* or appeal to emotion, *ethos* or appeal to authority and *logos*, the appeal to reason.

With the coming of writing, logos began its rise to dominance over the other two. (Illich, 1989) Reason was more easily captured by the written word and only reason could stand up to the extended scrutiny which the permanence of the written word allowed. In a literate world, reasoned arguments were the most persuasive. Indeed, acceptance of the principles of reason became, and still is, a minimal condition for meaningful discourse.

In this rational world, there are many domains where discourse takes place within clearly articulated principles of reason. Perhaps, the epitome of reasoned discourse occurs in science, based on the scientific method.

More recently, the claims of complete rationality, even of the scientific enterprise, have been challenged, but these claims are of course supported by reasoned arguments. Our basic commitment to reason seems secure. At the same time however, we see the

[1] Some parts of this section have been published in Goforth (1995).

return of classical rhetoric in the 'post-literate' broadcast media. Pathos and ethos are back.

In this admittedly personal view of the landscape of persuasion, critical thinking is taken to mean:

(a) the ability to recognize the difference between reasoned and irrational argument and the inclination to embrace the former while rejecting the latter;

(b) the ability to recognize and apply the rules and conventions of particular domains of discourse;

(c) the ability to construct persuasive arguments and to evaluate and criticize such arguments;

and

(d) the ingenuousness to be persuaded by a strong argument.

1.3.2 Current State of Educational Software for Similar Purposes

While rhetoric has been a worthy topic of study for thousands of years, there is a curious gap on this topic in modern education. Software support for the learning and the doing of critical thinking is virtually nonexistent. Programs where we might expect to find it, we do not. Consider the framing of arguments for example:

- Creative writing software supports idea generation at the brainstorming stage but glides over writing the first draft - where critical thinking skills are required - to focus again on editing.
- Some word-processing programs are claimed to have outlining features which help with the drafting of a document. These features typically create hierarchical structures

but offer no guidance or analysis of the completeness or appropriateness of the organization.

In the area of criticism, support is no better. Many programs offer the framework for critiquing, either one's own work or the work of others, but the emphasis is on revising as editing. Learning how to critique the reasoning is implicitly assigned to activity outside the software.

Collaborative writing programs follow a similar design with added features to support communication among participants. Again they focus on the facilities (electronic margin notes for example) more than the critical skills.

1.3.3 Current State of Hyperintelligence Tools of Similar Design

Moving from educational software to a business environment, we encounter programs of similar design for collaborative work which address similar issues in a more substantive way. None addresses critical thinking directly but there are many which support related problem-solving skills in work groups. For example, support for group decision making encourages the members to think in terms of *issues*, *proposals* and *decisions* and moderates the process of arriving at a consensus. These programs are a source of ideas and caution for the critical thinking software of this project.

In the literature of group work support systems, some problems are described which have been investigated in the course of developing the critical thinking software. It has been a secondary goal of the project to propose and test solutions to four of these problems in particular.

1.3.4 Computer-Supported Design

Computer-supported design environments provide professional designers in a variety of fields with tools for activity which is closely related to critical thinking. In these environments, the designer is able to extend the tool set, effectively enhancing the design environment. This capacity is distinct from the employment of the tools to create design artifacts and the distinction is similar to that between the activities of the instructor as environment builder and the learner as environment user. Design environments have influenced the implementation of the critical thinking software.

1.4 Organization of this Dissertation

The literature of these relevant areas, (i) instruction of critical thinking, (ii) related educational software, (iii) software supporting collaborative work (so-called hyperintelligent systems), and (iv) computer-supported design is surveyed in chapter two. The final section in this chapter makes the case for the fundamental design decisions concerning the project which were based on this literature research.

Chapter three describes the methodology of the project. Because the product is a theoretical model developed and tested as a computer program, it is important to specify the criteria for a successful model and for and successful implementation. It is also important to describe how the actual model and software are to be judged against the criteria. After a specification of the software development environment, the chapter concludes with an extensive description of how the methodology for judging the model and software contributed to project development.

The detailed descriptions of the final model and software are found in chapter four. After the theoretical explanations, an example of the program's behaviour under the control of a learner is included together with an investigation of instructional design with the system. The chapter concludes with a discussion of one instructor's experience with the software.

Chapter five begins with some reflections on the success of the research methodology of the project. This is followed by a critical review of the final version of the model, both in relation to the stated primary and secondary goals of the project and in terms of other issues and insights which emerged during development.

The concluding chapter summarizes the work in relation to the current state of instruction of critical thinking and suggests where the project will go next, toward a better model of critical thinking and toward research into cross-disciplinary discourse.

2. Lessons from the Literature

Distinct bodies of research have influenced the basic design decisions from which this project began. These areas are surveyed in the first sections of the chapter. The final section describes the relevant issues and the choices that were made based on these investigations.

2.1 Learning of Reasoning and Critical Thinking

In the vast literature on critical thinking and how it can be learned, there is no consensus on a definition of the term. At the core is rationality, a commitment to reason rather than irrationality.

There is general agreement that critical thinking is distinguished, as 'higher level', from lower level skills like memorizing or rote application of algorithmic methods such as arithmetic operations (e.g., Paul & Nosich, 1992).

Critical thinking is also distinct from the unstructured, informal, and uncritical thinking associated with brainstorming or flashes of insight. These modes typically precede critical thinking. Sometimes, the solution of a problem is associated with the informal thinking - the "aha" experience - and the stage of critical thinking which follows is to formalize the result (e.g., Polya, 1954). In other situations, the informal stage generates ideas and a solution emerges from the critical thinking stage when the ideas are combined.

In either case, there is plenty of room within critical thinking for creativity. In an analytic exercise, like formalizing insight into proof or evaluating a reasoned argument from someone else, the critical thinker is (re)producing 'backwards' and evaluating a rational structure. In a constructive situation, such as design, or writing to learn, the product or thesis is generated by reasoning 'forward' within the constraints of the known facts and conventions.

Critical thinking is also contrasted with the revising or editing process which follows it. This stage is associated with the format and presentation of the rational structure which results from the stage of critical thinking. Editing should not change content.

Hence, there would be little disagreement that critical thinking is both generative and analytic and that it is a creative activity. It is less formalized than a deterministic algorithmic activity but more formal than pure insight. Critical thinking is often described as an 'art' with formal constraints and heuristic strategies applied in a feedback loop of trial and error.

Within this general framework, a variety of approaches to the problem of teaching critical thinking is found because of

(a) different proposals for the elements from which a reasoned argument is constructed,

(b) different heuristic strategies for doing critical thinking,

(c) emphasis on particular domains of discourse,

and

(d) different instructional designs.

The area of design and problem solving in the professions (e.g., mathematics, engineering, architecture) has produced the most comprehensive and advanced models for critical thinking. The classic "How to Solve Problems" (Wickelgren, 1974) covers most of the basic ideas in a practical if prescriptive style. Because of the quantifiability of many aspects of these domains, the use of software in support of professionals and learners is also the most established. Description of design systems is left to the section 2.5.

Design provides important lessons for all critical thinking software development but we must be aware that quantifiability is atypical. As Steven Toulmin observes,

> "Mathematical arguments alone seem entirely safe: given the assurance that every sequence of six or more integers between 1 and 100 contains at least one prime number, and also the information that none of the numbers from 62 up to 66 is prime, I can thankfully conclude that the number 67 is prime; and that is an argument whose validity neither time nor the flux of change can call in question. This unique character of mathematical arguments is significant. Pure mathematics is possibly the only intellectual activity whose problems and solutions are 'above time.' A mathematical problem is not a quandary; its solution has no time limit; it involves no steps of substance. As a model argument for formal logicians to analyse, it may be seductively elegant, but it could hardly be less representative." (Toulmin, 1958)

Among the authors of texts on critical thinking in its more general guises where the solutions are not 'above time,' there is little common ground beyond the broad properties described above. More disturbingly, the texts are typically incomplete.

The work of Steven Toulmin, a dominant rhetorician of the twentieth century, is typical. In "An introduction to reasoning" (Toulmin, Rieke & Janik, 1984), there is excellent treatment of the elements of an argument, particular argument strategies and domains of discourse, but little on compound chains of reasoning or the processes of critical thinking[2].

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[2]In the proposal for this project, I intended to use Toulmin's model with extensions for these omissions as the basis for the software. This approach had to be abandoned. See section 3.3.3.

Paul and Nosich (1992) have formulated a model on which to base standards for a (U.S.) national evaluation of critical thinking skills. They define eight elements of reasoning (EORs) in a unit of argument which is similar to Toulmin's. The main distinction is that they include 'implications' as an element of an argument whereas Toulmin would see the extension from claim to implication as another argument, albeit a simple one. Paul and Nosich tabulate standards for manipulation of each EOR together with examples of deficiencies, examples of good and bad reasoning and feedback to assist 'bad reasoners.' Theirs is very much an evaluative and editorial approach with no process model and no consideration of relations among the EORs.

In their critical reading text, Walker and McClish (1991) have a simple and clear model for building compound arguments but their treatment of the elements of an argument is vague and incomplete. Missimer (1986) defines an unusually extended and complex argument unit that includes a dozen element types and he pays considerable attention to the tactics of critical thinking for generating and critiquing arguments. This is relatively rare but even he does not provide a model of the *process* of critical thinking.

If we look at the pedagogy of critical thinking, some of the best texts come from adult basic education. Barnes, Burgdorf and Wenck (1987) is an example. Whereas most of the advanced texts are organized into expository chapters concluded with analytic exercises, these authors have produced a workbook with a rich variety of activities which lead the learner to analyse existing reasoning but also to generate elements, arguments and critiques and to reflect on their own values and critical strategies.

Clearly, an exhaustive search of the literature on critical thinking is not possible. The works mentioned here and the others reviewed for the project span the field and capture the current state of development. One result of the research is evident: no complete model of critical thinking, as defined here, has been found.

2.2 Rhetoric or Logic as a Basis for the Software

The pressure within computer science to use logic as a basis for representation of reasoning is so strong that to do otherwise requires justification.

The commitment to logic as a basis for representing reasoning is not without its own justification. It has survived as the best alternative through decades of experimentation in representing human thought. The symbiotic relationship between psychology and computing dates back at least to the coining of the phrase 'Artificial Intelligence' in 1956. Since that time, computational models of mind have served both fields. Psychologists refined theories of mind by testing them as computer programs and computer scientists studied effective human methods for solving problems still beyond the power of their algorithms.

In the early period, systems were built on a variety of representational models (or were 'hacked' with no models) but ultimately, artificial intelligence came to be dominated by formal logic and achieved some success at emulating rational human thought in expert systems. However, the successes were limited mainly to the most structured and formal domains of thought. Attempts to apply the methodology of expert systems in less formal domains have run into the characteristic problems of incomplete and inconsistent information. These are fundamental theoretical problems which require extending the models of logic underlying the systems. While progress has been made, there are not many who would argue that the models are extended in ways that match the heuristics that humans use in noisy informational settings.

As Toulmin's quote earlier would imply, theorem proving is a successful computer application because a mathematical system begins with a set of accepted propositions as axioms plus some rules for combining propositions. Further propositions deduced by the system are unequivocally true and consistent. If a theorem is hypothesized, then reasoning can proceed backwards (abduction) to a grounding in the axioms if it exists. There may be distinct alternative proofs of the theorem but there can be no inconsistency.

Medical diagnosis systems are messier because the fundamental operation of diagnosis from symptoms to diseases is backwards, not deductive but abductive. In this case it *does* matter if there are alternative chains of reasoning because different diagnoses are implied. The situation is further complicated by the uncertainty even of forward reasoning: diseases do not always manifest in the same symptoms.

Nonetheless, medical diagnosis systems do function effectively, typically by adding probabilistic reasoning and many special case rules and by extensive 'tuning': machine diagnoses are matched to those of human experts and the probabilities are adjusted and more special rules added as necessary until the performance is acceptable.

Diagnosis is tractable because the domain is relatively narrow, and all the diseases and symptoms are known, even if the relationships admit of some uncertainty. In less well structured domains, the logic model is ineffective and progress with non-monotonic logics has been slow.

Rhetoric provides an alternative model for representing human thinking skills. As rhetoric is founded on the notion of persuasion rather than proof, it is not compromised by inconsistency. In fact, the environment of rhetorical persuasion is discourse which implies conflicting information.

A rhetorical argument always develops from the known and agreed information toward the questionable or unknown. Theorem proving would, in accord with logic, proceed from axioms to theorems, but diagnosis would also proceed from symptoms -- the known -- forward to disease -- the unknown -- in a rhetorical model. Here is the essence of the difference from the logical model. In logic, the roles are the invariants: a cause is always a cause (known or unknown) and an effect is always an effect. In rhetoric, the format is the invariant - the accepted information is the starting point and the uncertain claim is the end.

There is, of course, a cost for the more accommodating format of rhetoric. Representational power is purchased at the price of analytic power. However, that price is not high as the model and Peitho software demonstrate.

2.3 Existing Software

Investigation of educational software is ongoing in all domains of curriculum. The general trend has been from programs which promote and test memorization through software for developing and demonstrating basic skills to environments which promote understanding and exercise problem solving skills. While the problems to be solved are domain specific, the skills required are being recognized as similar. These skills are the skills of critical thinking.

In the domains 'above time,' with underlying quantifiable theory, the use of design environments to teach problem solving skills is well established. These are discussed later. In domains where argument is rational but not quantifiable, the design appraoch is virtually unknown. As I intend to put forward a design-based model for critical thinking software, it is important to look first at the current alternatives.

Some domains are more advanced than others in developing software for learning critical thinking. In the pedagogy of writing, the stages of the writing process are usually taken to be

(a) idea generation,

(b) thesis development,

(c) first drafting of argument

and

(d) revision, and a lot of software development has taken place around this model.

Critical thinking would seem to be essential to the final three stages of the model but none of the systems reviewed address it adequately.

Nonetheless, there is a lot to learn from experience with writing software. LeBlanc (1993), in a survey of writing systems, summarizes the lessons. As in most problem solving software development, the creators of recent writing programs are convinced that the best approach is to provide a tool to support writing rather than a tutorial. Some developers express concern that the environments be model-based and not just a collection of features. Others want to assure that the programs are able to reflect rather than restrict the thinking of the users.

A typical example is Writer's Helper (Conduit, 1993) which organizes writing as a three step process of Prewriting, Drafting and Revising. Prewriting is a brainstorming activity which ends with 'Organize' operations. These operations emphasize document structure over argument structure but do have some capacity to build 'Trees' and debates. There is no analytic power. The result is exported to a word processor for the second step of drafting and returned for revising where the emphasis is on editing and presentation style. There is a model for the writing process but the treatment of reasoning and critical analysis within it is superficial.

A program of a different type which suffers from a similar weakness is Nakell & Helfgott (1994). This program supports contemplation of a problem and the creation and organization of a plan. The environment is based on a sophisticated visual interface which organizes the representation of the plan as a graph. The tools for manipulation of the plan in this format are extensive but it is little more than a hypergraph drawing facility. The user has no assistance in developing or evaluating the plan.

Quite a different situation exists in curricula associated with professional design. The use of design tools by professionals is well established so the focus is on how to train beginners on the use of these tools. This development is supported by a considerable base of design theory on which the tools have been constructed Many apprentice design environments have been built.

The theory of design is based on a goal of creating an artifact so that some set of properties is optimized while satisfying some set of constraints. Any particular artifact can be evaluated with respect to the properties and constraints. The art of design is in the heuristic strategies for selecting the features of the artifact. This is done in a trial and error fashion in which an artifact is re-designed and re-evaluated.

A computer program supports design by providing the capacity to select features for the artifact and, more significant for critical thinking, the capacity to automate the evaluation of the artifact with respect to the properties and constraints. The automation is based on the 'above time' features of the formal domains. With these features available, the question of learning to design then focuses on the heuristics of artifact production.

LOGO was one of the first learning environments in the design mode. The goal is to optimize the match between the execution behaviour of a LOGO program and the target behaviour. The constraints to be satisfied are the syntax rules of the programming language. LOGO's inventor, Seymour Papert, recognized one of the first advantages of the tool environment: the features of the language - the error messages and the output of the program - concretize the concepts the beginner is trying to learn[3]. The code-and-execute activity also implements the rudiments of a feedback strategy.

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[3]Papert makes a further relevant claim that the discussion of program designing leads to self awareness of thinking strategies.

Unfortunately, beginners are not good designers. Guzdial et al (1992), continuing in the area of software design, have experimented with an environment, called the Goal-Plan-Code or GPCeditor, which provides more supports and constraints for beginners. The environment specifies three stages of operation: problem decomposition, solution synthesis and debugging. For the first two stages, GPCeditor provides constructs above the programming level and for the third, there is a library of code segments and aids for semantic debugging. An example of a constraint imposed is that the learner cannot import a segment of code from the library unless it is specified in a feature of the design from the earlier phases.

There is an increasing recognition that the design model has potential in other subject areas. A main concern has been that the basis of the design environment is the automation of the evaluation process which matches the artifact to the goal properties and the constraints. This automation powers the feedback loop so the beginner can learn by doing. The design-based professions are uniquely placed, the argument goes, because the properties and constraints of their content areas are quantifiable and this is 'seductively elegant, but it could hardly be less representative' as Toulmin says.

The argument against the design model is challenged in two ways. At the level of curriculum, there is a case to be made that some subject areas should be reconstituted as design disciplines. Jungck et al (1992) argue that science is better conceived in this way so that students see science as the posing and testing of hypotheses. They have created a design environment for genetics in which students frame questions and design and conduct experiments to answer them. The program constrains their activity by simulating results to the experiments they conduct.

A second route to adapting the design model is to investigate whether the potential for automating optimization of properties and the satisfaction of constraints is as weak as presumed in the less elegant domains. Burns developed a creative writing tutor which asked a student a series of questions. The program was based on his observation from years of teaching that he did not need to know the topic the student was writing about in order to advise. (LeBlanc, 1993) There is potential for invariant knowledge to be incorporated into design-type environments also.

Introducing a collection of papers on design-based learning systems, Balestri, Ehrmann & Ferguson (1992) make the case that the design paradigm is doubly valid. First, the design approach is an effective way to convey the analytic skills needed in many disciplines, and second, the exercise of designing is an ideal participatory activity for learning content. The title of the collection is *Learning to Design, Designing to Learn*.

2.4 Tutors and Tools

Recourse to logic is not limited to the representation of domain knowledge. A main use of expert systems in education is student modeling. In tutorial software, the student model is a data structure which represents the student's understanding of the course content so far as this can be ascertained from the dialogue with the student. Even in fairly formal domains like arithmetic, this modeling is difficult because the expert system must abduce both the correct and flawed skills of the student. At the same time, the model is useless unless it is a faithful representation because the tutor module uses it to plan interactions with the student.

Critical thinking is clearly a more sophisticated domain of expertise than arithmetic so the prospects of modeling student understanding are bleak. The problem is compounded because critical thinking is always thinking about something; that is, there would be another domain of knowledge layered on top of the critical thinking representation in the student model. Without being able to model the critical thinking processes of a human thinker, a developer of software can have no hope of building a tutorial program.

There is another reason for avoiding the tutorial approach. Control of the interaction between computer and student is an important factor in learning outcomes. Tutorial programs retain this control whereas learning is encouraged when the student takes more responsibility for directing the interaction[4].

An alternative approach which leaves the student in control is called the 'tool' model because the student interacts with the software in a fashion similar to the way a computer user employs a productivity tool such as a word processor. The student learns by solving a problem using the software. In mastering the features of the program, the student is mastering the concepts of the domain in an active, meaningful way, motivated by the goal of solving the problem. Computer supported design systems fall into the category of tools.

2.5 Computer-Supported Work Systems

Aside from professional designers, many workers use productivity tool software. VanLehn (1985) described his experience with Xerox NoteCards, a forerunner of Apple's HyperCard. He called it a software aid for "formulating and managing arguments" and proclaimed its effectiveness in tightening the arguments and even changing the claims of some of his theoretical work. A class of research systems which investigate this type of application has come to be known as hyperintelligence systems. In many ways these are the professional versions of the learning software developed here.

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[4]My own investigation of the importance of learner control in the effectiveness of computer-assisted learning supports this. (Goforth, 1994)

The gIBIS system (Conklin & Begeman, 1988) was a turning point in the evolution of hyperintelligence systems. These developers implemented, in interactive graphic form, a system called IBIS which Rittel (1978) created to manage 'exploratory policy discussion.' This tool generated a graphic model of the discussion in terms of nodes of specific types:

- issues,
- positions as suggested solutions to issues

  and

- arguments supporting or rebutting positions.

The authors found that users had some trouble getting comfortable with gIBIS but ultimately found it productive because it focused their thinking and revealed inconsistency and incompleteness. It also exposed and restrained 'game playing' in groups and made assumptions explicit. Conklin and Begeman attribute the success to a semi-structured environment that fits the actual decision making process.

The authors are also quite clear in their description of the shortcomings of gIBIS. This analysis has influenced ensuing research considerably. For example, Lee (1990) built a system that included decision support for selecting which position best solved an issue. Carlson and Ram (1990) extended the IBIS model beyond decision making with other node types that better tied the structure into conditions for planning and implementing solutions. They further attached code to the nodes so alterations caused cascades of updating in the style of a spreadsheet. Ramesh and Dhar (1992) improved on the decision support by capturing the history of a design process so decisions could be reviewed and reconsidered. They also provided users the power to define new types of nodes that could be domain specific.

The notion of giving users the power to define new node types introduces two convergent issues of importance in both work and learning. The ability of the system user to define new node types moves the line between design and use of the system. In essence, the designer has an altered role to provide a more generic system and user-level tools for tailoring it. This intermediate level of access has evolved over the years. Originally, on-site programmers rewrote the code; later, the capability for writing macroprograms was included for the local 'gurus' to use; now, the general user was being empowered.

Arguing that a first design seldom exactly meets the needs of a user and that the needs change over time anyway, Henderson & Kyng (1991) have investigated and promoted what they call the 'design-in-use' paradigm. Design-in-use is not a new idea. General purpose software such as word-processors and spreadsheets have long had macro-instructions which allowed users to tailor programs to their specific needs. What the authors are proposing is that all programs, including those custom-built for specific purposes, need to include this capability. In an educational setting, this translates as a claim that learning software should be revisable, presumably by the instructor, and by the learner as well, once a sufficient level of mastery is achieved.

2.6 The Basic Design and the Literature

From the literature review, several basic decisions were taken concerning the approach to the model.

2.6.1 Model of Critical Thinking.

The decision to base the project on rhetoric rather than formal logic is the starting point to defining the model. From the variety of issues stressed by authors of critical thinking texts, it is clear there is no consensus concerning a definition or model of critical thinking which could be used as a basis for software development. It also seems both arrogant and naive to think I could propose a better model than the legion of instructors who have already tried. Instead I have taken the union of all the contributions as an implicit definition of the territory to be covered by a generic system that would then be usable to represent these and other approaches.

There is agreement that

(i) reasoning must be based on an accepted body of facts and principles;

(ii) the goal of reasoning is the establishment of further fact(s) and/or principle(s), based on the agreed ones.

In the generic model developed here, all information is represented in statements. If a statement is accepted as a basis for reasoning it is called a **fact**. If a statement is to be established through reasoning it is called a **claim**. A set of facts assembled and organized to establish a claim is called an **argument**.

Either implicitly or explicitly, critical thinking must deal with situations where establishment of a claim requires that several arguments be made. Once a claim has been established by an argument, it can be used as a fact in a subsequent argument. A connected collection of arguments is called a **chain of reasoning** and the ultimate claim established by the complete chain of reasoning is a **major claim**.

This construct can be further specified to match any of the models discovered in the literature.

The other aspect of critical thinking which must be modeled is the process: how is the chain of reasoning manipulated? Again there is no consensus so I have defined types of activity which can be used to express the heuristics advocated in the literature.

(i) **Information gathering**: the statements (either fact or claim) are assembled.

(ii) **Structural organization**: a chain of reasoning is constructed by grouping statements into arguments and connecting arguments.

(iii) **Critical analysis**: the chain of reasoning is evaluated to ascertain its strengths and weaknesses in justification of the major claim.

Hence the model is a representation of the product and process of reasoning. Initially, I proposed to use the basic pattern of analysis (Toulmin, Rieke & Janik) as the definition of argument and add extensions. This plan was dropped during development of the model. The final model is discussed in detail in chapter four, section 4.1.

2.6.2 Type of Software.

From the investigation of related software, especially in curricula of writing and design, it is evident that a software tool is the right form for the program to test the model. The design is based on a tool to support expert critical thinking. The learning activity involves mastering the skills of critical thinking by learning to use the tool. The strong analogies between the processes of design and writing (Jungck, Peterson & Calley, 1992) suggest that the success of design systems for learning can be realized in more areas where critical thinking skills apply. The design of the software can accommodate the feedback loop of re-design (information gathering and structural organization) and re-evaluation (critical analysis).

2.6.3 Design-in-Use

The generic nature of the model of reasoning which underlies the critical thinking software requires some means of expressing the further details of any particular curriculum for learning critical thinking. This facility is provided by a design-in-use approach which extends the process model and permits the user to specify more about statements, argument strategies and criteria for evaluation. In a learning environment, the instructor does the design, but the learner takes over this activity as expertise develops.

2.6.4 The Proposed Model as Educational Technology

Professional design tools, from spreadsheets to computer-aided-drafting to symbolic mathematics, have found their way into classrooms. None of these programs was first devised as an educational environment but all have become essential learning tools. There are two reasons for this.

First, these tools have fundamentally altered their disciplines and have become integral parts of the curriculum. Modern accounting cannot be defined without spreadsheets.

Second, design environments turned out to be good environments in which to learn, for the many reasons which have been described above.

The model described in the following chapters attempts to define the same kind of environment for learning to reason critically. As no professional tool exists to conscript into educational service, the model must address both the 'doing' and the 'learning,' both the professional activity and the learning environment. The advantage of this situation is that learning can be factored in from the beginning much as paedogogical concerns were addressed in the design of the programming language LOGO.

The scope of the development is broad so it must, of necessity, be limited in detail. In particular, the design of an acceptable interface would require significant resources but is only indirectly driven by the underlying model. Hence the software has been developed far enough to establish the representational sufficiency of the model but there can be no claim that Peitho, as is, could increase the productivity of a user.

Claims for Peitho as a learning environment are similarly broad and non-specific. Whether particular problems in the instruction of critical thinking could be addressed and solved in the environment has not been directly considered in the design. Rather, the power to represent a variety of models used in teaching critical thinking has been established. If the authors of those models created them in response to their perception of student needs, then those needs can also be attended to in the participatory environment of Peitho[5].

If Peitho cannot be said to address particular instructional concerns, it does already offer something substantial to advance the instruction of reasoning. The model stakes out the territory which must be explored by any curriculum in critical thinking: when a particular approach to teaching reasoning is encoded in Peitho, inconsistencies and incompleteness are unveiled. Before instructional design address learners' real difficulties with reasoning, we can at least try to assure that no incidental ones are introduced.

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[5]Whether Peitho meets those needs any *better* is considered in an evaluation of the software by an instructor who suggests some particular problems of instruction which can potentially be resolved with Peitho. Of course, the question will only be answered satisfactorily when an interface is completed and Peitho can be evaluated by learners.

3. Research Methods

The research in this project has been conducted as a design project very much in the fashion described in the previous chapter. The ultimate goal is a model of reasoning and a program based on it for learning critical thinking. As a design project, the activity is a heuristic and artful process which attempts to optimize the properties of the product while satisfying the constraints.

This kind of activity, as exploited in LOGO or GPCeditor, is common in computer science but there has been concern that it is a sloppy approach that produces poor research. As I have proceeded by this design approach, I have organized my activity to avoid these pitfalls. In this chapter, the research model which I have adopted, based on Cohen (1991), is described in detail then the means of evaluation of the product is outlined. The features of the project are defined in terms of the research model and the specific criteria for evaluating the project are established.

After a section describing the programming tools, the cycle of development is documented. The cycle of development is the particular version of the design strategy as Cohen describes it in the research model. The progressive refinements of the model and software are described in this context.

3.1 Cohen's Computer Science Research Model

The research model is one proposed by Cohen (1991). Based on a meta-analysis of research in artificial intelligence, he criticizes the discipline as dominated by two types of research, either model building with no concern for external validity or system building with no concern for theory or generalization. Both types he criticizes for lack of experimental rigour: no hypotheses or predictions and hence no validation of results.

In fact, the conventional wisdom has been that empirical research in computer science in general is uniquely privileged. As Newell and Simon put it in their Turing Award Lecture,

> "Each new program that is built is an experiment... We can relate their structure to their behavior and draw many lessons from a single experiment. We do not have to build 100 copies of, say, a theorem prover, to determine statistically that it has not overcome the combinatorial explosion of search in the way hoped for. Inspection of the program in light of a few runs reveals the flaw." (Newell & Simon, 1982)

But, as Pollock (1992) says, we cannot be so sure in the evaluation of programs that operate in complex environments, even if we could with isolated systems like theorem provers.

In his proposal, Cohen nonetheless acknowledges the reality of computer science research that separates it from the quasi-experimental environments that are typical of empirical research in the social sciences. Many experiments are probes of complex but deterministic activity spaces that can be sampled in organized ways, either under full control or through simulation. As a result, computer scientists see theory and model building in a very tight feedback loop with implementation and testing.

If the system under investigation has a user interface as a major factor then the claim for this approach to evaluation is weaker, We can only say that the program that emerges has satisfied some set of necessary conditions because disproof by counterexample has led to redesign. Whether the program form is sufficient cannot established, even to the extent described above, because the essence of its operation is only testable by real users[6]. Given this situation, the goal of this project is to establish the viability of the software proposed. That is, I have produced a version of the software which is proved to have the representational and manipulative power claimed but has not yet evolved through design and testing with users[7]. To get to this stage, I have applied Cohen's methodology.

> "I call the methodology, modeling, analysis and design (MAD). MAD involves seven activities:
>
> 1. assessing environmental factors which affect behavior;
> 2. modeling the causal relationships between a system's design, its environment and its behavior;
> 3. designing or redesigning a system (or part of a system);
> 4. predicting how the system will behave;
> 5. running experiments to test the predictions;
> 6. explaining unexpected results and modifying models and system design; *and*
> 7. generalizing the models to classes of systems, environments, and behaviors." (Cohen, 1991, p.27)

Figure 3.1 provides an overview of the process of Cohen's model. In the following subsections, the research model is described according to Cohen's activities.

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[6]Hence, we see the usual strategy of early releases of 'beta versions' of software before official product launches.

[7]In these circumstances, the interface shortcomings can be expected to interfere with the evaluation of the underlying model.

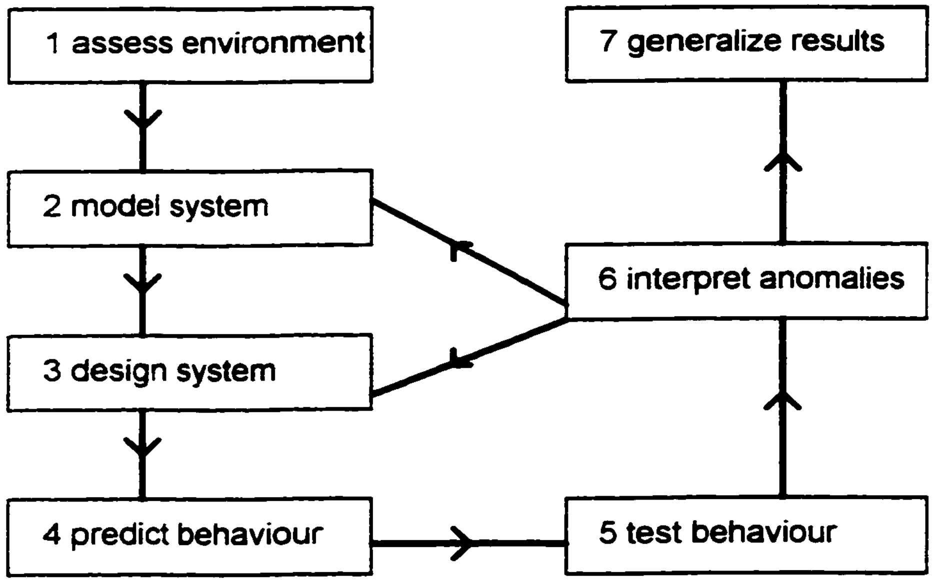

Figure 3.1: Cohen's model for software based research

3.1.1 Environmental Factors

The environment of the project is essentially the current state of knowledge as described in the literature. Assessment of the environment, as Cohen says, establishes the assumptions under which the model is developed. These assumptions are described in chapter two.

However, another interpretation of environment is required for the purposes of the research model: What is the environment in which the software will be used? This definition is the basis for later stages of MAD.

The environment in which Peitho will be used has the following parameters:

User The user of the system may be an expert critical thinker using it as a productivity tool, or an instructor preparing the system for learners, or a learner.

The operationalization of this parameter is left to section 3.2.3 when the system research strategy is described.

Domain of discourse The conventions of reasoning depend on the domain which may be, for example, scientific, legal, or aesthetic.

Type of activity The purpose of using the system may be for creating a chain of reasoning or for critiquing. The creation of a chain of reasoning is operationalized here in two modes, one to support a claim which is already known, and the other to include exploration and generation of the claim. Critiquing is also split to distinguish analyzing an existing chain of reasoning from engaging in an ongoing dialogue. Hence the four activities are

i to construct a chain of reasoning in support of a specific claim,

ii to generate a claim implied by a set of information,

iii to critique an existing chain of reasoning

and

iv to engage in dialogue for reconciliation (synthesis, selection, arbitration, accommodation, assimilation...) of conflicting claims.

3.1.2 Model

The theoretical model, however it is defined, must be usable in MAD to answer two kinds of question: *How will design changes effect system behaviour?* and *How will environment changes effect behaviour?* In this project, the model defines the idealized behaviour of the software so changes in the model are mappable into the potential behaviour of the system. This potential change in behaviour is transformed by the constraints of the software development but the separation of the effects of the model from those of the software design is not a problem.

To answer questions of the second type, it is necessary that the changes in the conditions of the environment (the parameters above) be expressible in the language of the model.

3.1.3 Design

In Cohen's terminology, design is used in much the same way as described in chapter two. He is referring to the programming step of implementing the model as faithfully as possible, subject to the constraints of the programming language. In this project, the emphasis is on the representational and analytic aspects of the implementation which are essential to evaluating the model. Other properties are programmed as required to complete the functionality of the system but there is no attempt to optimize the design of these non-implied features including, for example, the user interface or help facility.

3.1.4 Prediction

The predictions concerning behaviour of the system are essential to both formative and summative evaluation of the project. The summative evaluation is based on the original prediction while the predictions for the current design are the standard against which actual behaviour is matched to identify required changes.

The original proposal contained the predictions concerning the project software. Primary predictions define the success of the project relative to the goals of the reasoning system.

1. A model of the meta-structure of a chain of reasoning will be developed. An argument stored in the model as implemented in the software will *display its form, inviting understanding, appraisal and challenge*. **(prediction - the**

structure and meta-structure will be complete in the sense of being able to represent any argument format[8].)

2. A model of the process of reasoning will be developed which, by concretizing the manipulation of the structure, permits, to varying states of development, the following activities[9].

i *formulation of a reasoned argument in support of a claim* **(prediction - completely achievable)**;

ii *plausible reasoning in search of a claim* **(prediction - demonstrable to a degree which supports a claim that plausible reasoning tools can be integrated with the structures of reasoned argument)**.

iii *analysis and criticism of a reasoned argument* **(prediction - completely achievable)**;

iv *dialogue for reconciliation (synthesis, selection, arbitration, accommodation, assimilation...) of conflicting claims* **(prediction - not achievable but some speculations and suggestions about how to proceed should result)**;

The proposal also contained predictions concerning the secondary goals of the system to contribute to the research in hyperinteligence systems:

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[8]By implication, this will be achievable in any domain of discourse as defined in the parameterization of the environment

[9]By the different users as specified in the environment and detailed later.

1. It is hypothesized that linear summaries of hyperstructure content would help with an identified problem of orienting late starting participants in a group process. **(prediction - Linear structures can be created from the hyperstructure)**.

2. Generic element types (roles) create a freer environment for users to capture first vague notions of a problem. **(prediction - generic element types can be provided.)**

3. Explicit modeling of process would strengthen the modeling of hyperintelligence systems. **(prediction - the stages of reasoning [information gathering, organization and analysis] are an organizing principle that will anchor a model of the process of reasoning.)**

4. The use of software calls will retain the domain independence required to allow cross-domain synthesis. **(prediction - the expressive power of software calls will allow users to create domain dependent structure independent of the language of the tool itself.)**

These predictions will all be considered in gauging the success of the project in chapter five.

The other use of predictions, in the evaluation of the current design and model for purposes of revision, requires that explicit predictions be made based on the current design. These are found in the next section in the description of the development cycles of the project.

3.1.5 Experimentation

Once the predictions of a particular model and design are defined, the system is run so actual behaviour can be matched to them. There are four possible results: the model and the design are sufficient; the model is sufficient but the design is incomplete; the model is insufficient but may be revised based on what the experiment reveals, or the model is intrinsically flawed. The experimentation tests the static model of structure and the dynamic model of the reasoning process[10].

3.1.6 Explanation

The four results of experimentation lead to different activities. If the behaviour meets predictions then the system is complete and the project is finished and ready for generalizing[11]. If the discrepancy is explained as a programming problem, then the research recycles to the design stage; if the model is inadequate then to the modeling stage. If the explanation of the problem is a fatal flaw in the design then the project is a failure and that conclusion should also lead to some generalizations.

3.1.7 Generalization

The applicability of the model and design, as determined by the experimentation, is generalized to the range spanned by the environmental factors. In this case, the intention is to claim applicability to all domains where critical thinking is practiced by experts and learners. The claim is for the functionality of the single user system and for the potential of a cross-disciplinary multi-user system.

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[10]The original proposal states that usability is to be tested. This is not the actual case except insofar as the interface is sufficient to implement the features of the model.

[11]At an intermediate stage, the experimentation may match the predictions based on the current design without matching the complete goal behaviour. This situation, common in computer science, occurs in the case of an incremental development of the model that is successful as far as it goes.

3.2 Eisner's Connoisseurship and Criticism Evaluation Model

As stated in the proposal, the research is conducted according to a computer science model (Cohen's) but the result is evaluated as educational technology applying Eisner's connoisseurship and criticism methodology.

Eisner (1969) distinguished educational activities in two categories as *instructional* or *expressive*. Instructional activities have a well defined objective and success is measured by matching behaviour to that objective. This kind of activity is appropriate for the learning of the basics of a curriculum domain, the "codes and skills." In terms of critical thinking, learning to pick out individual statements and identifying the main idea of a passage are examples. In the environment of a design tool, a learner would be using the system features and satisfying the (automated) design constraints.

Expressive activities do not have an explicit objective but are designed so the learners apply the basic skills to purposes of their own. Evaluation of these activities is based on the quality and import of the students' work and requires, according to Eisner, that the instructor make an aesthetic appraisal much like a critic in the arts. In critical thinking, a teacher would be looking for quality of argument in a student's work rather than, say, expecting the student to reach a particular conclusion. In a design environment, expressive activity involves exploring the space of potential solutions bounded by the constraints and requirements. The instructor will be looking for value added beyond the minimal requirements of the problem.

Over the years, Eisner developed his concepts of aesthetic evaluation of expressive activities both as a means of measuring student progress and as a research methodology for educational processes now known as **connoisseurship and criticism**.

Three aspects are involved in connoisseurship and criticism. First the critic/evaluator describes the activity or process, aiming to capture the salient features, both factual and artistic. Second, he interprets the activity to account for those features, based on an understanding of the domain. Third, he evaluates the result and the activity according to criteria appropriate for the activity.

I have applied Eisner's methodology to this project in two ways: *connoisseurship and criticism* structures the explanation activity of the research model, and *instructional and expressive activity* is the organizing principle of the environment of activity when the software is used. These are described in sections 3.2.1 and 3.2.3.

3.2.1 Evaluating the Project

First, the software is judged as an educational environment by Eisner's approach fitted into Cohen's research model as the explanation stage (step 6, Figure 3.1): the experimentation is described; the description is interpreted according to the model and design, and the resulting interpretation is evaluated relative to the predictions and the goal.

The description is supposed to be salient and the interpretation is supposed to account for the phenomena in terms of theory, in this case the model and design of the software. For valuing, appropriate criteria must be found which indicate the potential effectiveness of the system for learning. Eisner calls the expertise for this task connoisseurship. In this case, the expertise for making the salient observations, for interpreting them and for evaluating the interpretation is the connoisseurship of the educational technologist - as programmer (for interpreting and explaining the design) and as instructional designer (for valuing). In other words, the explanation stage must first determine if the model, design and behaviour are internally consistent (else the project returns to step 2 for remodeling or 3 for redesign) but there must also be some external criteria applied to predict whether the activity is worthwhile (so the results can be generalized in step 7).

3.2.2 Interpreting the Model and Design - internal validity

Peitho has been developed in Microsoft standard Visual Basic, first version 2.0 and later version 3.0. The faithfulness of the implementation design to the theoretical model is constrained by this programming environment. In theory, any sufficient programming language can do whatever any other one can, but there are practical differences. For practical reasons, some discrepancies from the model have been acknowledged but not redesigned. If the actual behaviour is deemed to demonstrate the desired properties, it is accepted even if it does not exactly match the prediction from the model.

3.2.3 Judging the Software as an Instructional Environment - external validity

The software must be judged relative to the environment in which it is to be used. As an instructional tool, it must meet the needs of the users: the learners, the experts and the instructors. To operationalize the situation, a set of five functional environments has been defined.

Instructional and expressive activities provide a starting point. This categorization (the second application of Eisner's methodology) captures the stages in mastering a design environment, first learning the tools and then employing them in individual projects. Eisner defined creativity in the expressive mode and associated it with the creation of new tools in the design environment. Augmented with the evaluation role which specifies who judges the design artifact and activity, this set covers the user types in the development environment introduced in section 3.1.1.

In category one, the user is a learner becoming familiar with the tools of the system. The activity is instructional and specific behaviour is to be demonstrated. For example, the learner has a small set of statements and a single argument strategy to work with. The task is to identify roles for the statements and thus arrange them into a coherent argument. The system provides some constraint on learner activity, keeping it syntactically correct. The learner self-evaluates while making tentative combinations of statements in the argument structure; the instructor makes the final judgment of the outcome.

Category two is expressive. The learner has mastered enough tools that real decisions need to be made in the course of developing a chain of reasoning[12]. The resulting artifact emerges from the learner's choices and the judgment by the learner and by the instructor is 'connoisseurship and criticism.' The system still provides syntactic verification.

The third category, of the expert user, differs only in placing all evaluation responsibility with the user.

In the fourth, the expert user engages in creative activity, taking on the power to build templates of new models of reasoning. The system continues to provide syntactic support, assuring that the new templates are well-formed but the user is responsible for the semantics of the model and the heuristic advice which guides the application and judgment of the templates in expressive use.

The fifth category considers the case of the instructor using the same powers with a different purpose. Instead of building templates to extend the capacity of the design system, the instructor is creating microworlds for instructional and expressive learning.

This description can serve as the basis for evaluation. It allows the parameterization of the activities in a way which is identifiable with the software environment. This is done in Table 3.1 which summarizes the user categories.

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[12] As described in chapter 4, there are many factors which can be presented in either instructional or expressive mode, including number of strategies and number of arguments in a chain of reasoning.

	User	Activity	Evaluator
1	Learner	Instructional	Self, System, Instructor
2	Learner	Expressive	Self, System, Instructor
3	Expert	Expressive	Self, System
4	Expert	Creative	Self, System
5	Instructor	Creative	Self, System

Table 3.1: Users of a critical thinking system

In the table, the role of the system as evaluator has been added. In design software, the program provides the basics (codes and skills) but also formatively evaluates the evolving artifact according to the constraints and target properties. As stated, the professional design disciplines benefit from quantifiable constraints and properties as well as aesthetic ones. Here, the software for critical thinking is examined according to this table to see how much of the evaluation can be automated and how much is truly aesthetic and best left to the humans.

3.3 The Cycle of Development

In this section, the evolution of the model and software through its major versions is summarized. Each version of the model and design is briefly outlined with the emphasis on the novel features, and the desired behaviour is predicted. This is not intended to be a detailed description.

Based on the experimentation, the actual behaviour is described, interpreted and evaluated. The organization of the summary is based on Cohen's research strategy described in the previous sections. Each table shows these activities of MAD.

2. Model

3. Design

4. Prediction - representation / process

5. Experimentation - implementation and testing

6. Explanation - description / interpretation / evaluation

The current version is the basis for the detailed description (chapter four) and summative analysis (chapter five) of the project.

3.3.1 Version 1: Toulmin's rhetorical model of argument

The first version was based on the decision that a rhetorical approach was preferable to a logical one. Toulmin's basic pattern of analysis was taken as the structure of an argument. The literature (Stratman, 1982) suggested Toulmin's model could be extended to chains of reasoning and to plausible reasoning although he himself would not do so. Version 1 is summarized in Table 3.2.

2 model	• Toulmin pattern of analysis for arguments • processes for entering information, for organizing structure.
3 design	• statement entry from keyboard or existing document • user-created arguments from basic elements • templates for strategies available
4 prediction - representation	• any one step argument could be represented • multiple step arguments could be represented as steps but not connected together
4 prediction - process	enter facts and organize argument for: • organization (no analysis) of one step argument • formulation of one step argument • one step development of plausible argument
5 experimentation	• representation of Toulmin's examples • representation of Fischer's multi-step abduction example
6 explanation - description	• one step arguments could be represented but the 'modality' element was treated awkwardly • manipulation of the argument allowed the three claimed processes • the steps of the Fischer text conflicted because some statements were repeated in more than one argument • no constraint on the structure of arguments the user makes from the elements
6 explanation - interpretation	• modality is an element of Toulmin's argument but it is a property, not a statement • the statements in a chain of reasoning can be elements in different arguments within the chain • the type of an element is independent of the other elements
6 explanation - evaluation	• modality should not be treated like the other elements • statements are in a one-to-many relationship with elements of an argument and should be distinct entities in the model

Table 3.2: Version 1: Toulmin model of argument

3.3.2 Version 2: System model of a chain of reasoning

Based on the experience of the first version, statements were defined as distinct objects and a chain of reasoning was defined as a directed bipartite graph with node types of statement and argument. A statement could connect to arguments in which it was an element, both 'forward' to one in which it was evidence in support of another claim and 'backward' to one in which it was the claim. Every statement had to be supported somehow, but some were supported by external evidence (citations, beliefs, values,...) rather than arguments and formed the starting point of the chain of reasoning.

Missimer's (1986) basic pattern of reasoning has 12 elements so it could not be represented using Toulmin's (five) elements so the set of elements was inadequate. Missimer's pattern also contained an 'implication' element which was subsequent to the claim in the argument. It could not be accommodated in this version except as two arguments in sequence, one to establish the claim and a second to use the claim to establish the implication as another claim. See Table 3.3.

2 model	• chain of reasoning as directed bipartite graph • modality as property of argument rather than element • concept of external support
3 design	• choice of supports for statements including argument • templates of strategies to guide user in argument building
4 prediction - representation	• any argument strategy • chains of reasoning
4 prediction - process	enter facts and organize chains of reasoning for: • formulation of multi-step argument • multi-step development of plausible argument • organization (no analysis) of multi-step argument
5 experimentation	Missimer's pattern of analysis
6 explanation - description	• unit argument boundaries did not match with Toulmin's basic pattern • elements of Missimer's pattern could not be represented
6 explanation - interpretation	• 'grain-size' of models of argument are not consistent • boundaries between individual arguments of a chain are not consistent
6 explanation - evaluation	Toulmin's model is not an adequate basis for the model of reasoning structure

Table 3.3: Version 2: System model of chain of reasoning

3.3.3 Version 3: Generic Elements

The Toulmin basic pattern of analysis was replaced by a generic argument which contained elements, one of which must be a claim. External support was defined as another generic unit so a chain of reasoning was now a graph composed of *supports*, *statements* and *arguments*.

Particular theories of reasoning could be represented in the generic structure by defining templates based on a set of *roles* to describe the different elements, a set of *strategies* for the different arguments and a set of *evidence types* for the supports. Template sets could be read in from files.

Although an instructor could provide a set of templates for the supports, arguments and elements, a learner could alter them or add new ones. The system was sufficient but proved to be more powerful than necessary for the learner and did not allow the instructor enough control to constrain the learner's choices. At the same time, the progress of development of a chain of reasoning was difficult to monitor because there was no overview. Table 3.4 summarizes this version.

2 model	system model with generic elements, arguments and external supports
3 design	types for elements, arguments and supports defined or read from files
4 prediction - representation	same as previous
4 prediction - process	same as previous
5 experimentation	chains of reasoning based on several textbooks and passages for • organization (no analysis) • formulation • plausible argument
6 explanation - description	• sufficient representation and processes • complex, opaque structures and activity
6 explanation - interpretation	• no overview of chain of reasoning • designing elements, arguments and supports mixed with application
6 explanation - evaluation	• design power not needed by learner when types are provided • instructor not able to constrain activity of learner

Table 3.4: Version 3: generic structures

3.3.4 Version 4: Design-in-Use

The learner and instructor activities were differentiated in the model by factoring out the design activities in a formal design-in-use model. The designing of an argument strategy, for example, was now distinct from the use of the strategy in developing a particular chain of reasoning.

The sequence of ad hoc program changes to implement the evolving theoretical model had brought the software to a point where a complete redesign of the code was necessary. See Table 3.5.

2 model	design-in-use of • argument strategies • element roles • support evidence
3 design	• extended data structures and interfaces for design • two levels of access to templates for instructor (design) and learner (selection)
4 prediction - representation	same
4 prediction - process	• instructor can design constrained sequences of activities (like ICMs) • learner still has sufficient power
5 experimentation	• build template sets for learning sequences • test sequences for sufficiency
6 explanation - description	• satisfactory power for instructor/designer • sufficient power for learner • very buggy execution
6 explanation - interpretation	underlying data structures poorly organized
6 explanation - evaluation	too much incremental extension of original structures

Table 3.5: Version 4: Design in use

3.3.5 Version 5: Adding Analysis

While the program was being redesigned, the capability for the third mode of operation, analysis of the chain of reasoning, was addressed for the first time. The data structures were implemented so that graphical analysis of the tripartite digraph could be investigated. A linearized view of the chain of reasoning, based on a spanning tree, was added for summarizing the reasoning and for enumerating the problems in reasoning found by the analysis.

The analysis of the graph of a chain of reasoning was capable of identifying two categories of problem. First, if nodes were missing from the graph, then items were missing from the chain of reasoning. For example, an unsupported statement could be identified as could an unfilled role in an argument strategy. Second, if the graph was not well-formed, a corresponding structural fallacy could be identified. At present, only begging the question is recognized as a cycle in the directed graph.

The linear summary proved very useful as a way of locating the problems found by the analysis of the graph.

When a graph is well formed, the system can characterize a chain of reasoning only as to completeness; it cannot interpret the strength of the reasoning. This is a semantic problem. The epitome example is a pair of conflicting chains of reasoning with identical graphical structures. How are they to be compared?

2 model	chain of reasoning as graph
3 design	• redesign of data structures • graphical analysis functions • linearized representation of chain of reasoning
4 prediction - representation	• execution will be more reliable • linearized representation summarizes chain of reasoning and highlights problems found by analysis
4 prediction - process	• analysis will reveal some features of the chain of reasoning
5 experimentation	• execution more reliable • analysis of single step arguments • analysis of complete chains of reasoning • comparison of parallel chains of reasoning
6 explanation - description	• analysis reveals structure-based fallacies • linearized representation shows problems clearly • analysis reveals incomplete structures • analysis cannot address semantic evaluation
6 explanation - interpretation	• global structure of graph implies features of chain of reasoning • linearized representation provides context for analytic findings • well-formed chain of reasoning cannot be evaluated by graph analysis
6 explanation - evaluation	• graph analysis automates some 'constraints' and 'properties' of reasoning-as-design • linearized view shows potential of global view and suggests need for other views • evaluating strength of a well-formed chain of reasoning requires analysis of content

Table 3.6: Version 5: Adding analysis

3.3.6 Version 6: Adding Advice (Final version)

While evaluation of a well-formed chain of reasoning depends on evaluation of the content of statements and must be conducted by the user, there are still invariant features in the strategies. For example, statements should always be checked for ambiguity but the check is semantic. The theoretical model was extended to incorporate invariant features of the semantics and the design implemented them as advising.

This brief description evaluates the final version of the theory and software as an incremental extension in the development cycle. See Table 3.7 below. In the next chapter, the project is analyzed comprehensively and summatively with respect to the initial goals.

2 model	invariant features of semantic content
3 design	• advice about semantic features • parallel annotating opportunities for learner/user • annotations linked to linearized summary
4 prediction - representation	semantic invariant features can be made available as advice at relevant locations in the structure, together with annotation fields for users to log their comments
4 prediction - process	• learners can keep track of their semantic evaluations in annotations • instructors can include advice about specific templates
5 experimentation	• use generic system advice • create templates with advice • use templates with advice and user annotations
6 explanation - description	• advice can be included in templates • advice is available for evaluating chains of reasoning • annotation is available when needed • keeping track of annotations is confusing • displaying annotations with linearized representation is useful
6 explanation - interpretation	• advice model is successful • no overview to locate advice and annotations globally • linearized view locates advice and annotations with the statements
6 explanation - evaluation	advice model is successful and design shows potential but needs more development

Table 3.7: Version 6: Adding advice

4. Results

This chapter contains four sections. The first two explain the theoretical model and the software design respectively. The third section describes an example session of a learner using the software in an expressive activity. This example is referenced extensively in the analysis of chapter five. The section also describes briefly how an instructor would use the system and follows the design of templates for a particular model of critical thinking.

The final section describes a trial of the software by an expert in the instruction of argument. A university instructor developed templates based on a particular logic textbook and constructed chains of reasoning for example exercises from the same text.

4.1 Model - a Detailed Description of the Final Version

The theoretical model developed during the course of this research includes a structural framework for representing chains of reasoning and a process description.

4.1.1 Structure

The original plan of this project was to create a model of reasoning by extending the model proposed by Steven Toulmin. Toulmin's argument structure is a complete treatment of reasoning to establish a claim and applying it helps to reveal strengths and weaknesses of a particular case. However, Toulmin has little to say about chains of reasoning which involve several arguments. Neither does he discuss the process of constructing an argument. Thus the plan was to begin with Toulmin's argument structure, extend it to chains of reasoning and augment it with a new model of the process of construction.

Investigation of reasoning models proposed by other authors confirmed that Toulmin's is a landmark of completeness and clarity, as far as it goes. However, these investigations also showed that an exhaustive and formal model is not always necessary. For example, the standard five paragraph format (introduction, three supporting reasons and conclusion) is a structure that is useful in analyzing an essay. Identifying a claim and three supporting facts would suffice to guide this analysis but forcing the representation to conform to Toulmin's structure would introduce unnecessary complexity.

Toulmin's structure would, presumably, be effective for analyzing the content of each paragraph. Hence, it might be argued that this example -- the five paragraph essay format -- really shows a higher level of structure, a chain of reasoning already identified as missing from the Toulmin model.

Further research showed problems with other models of reasoning, at the same level of representation which Toulmin addresses. These models conceptualize the argument model by chunking it into concepts which violate the boundaries of Toulmin's features. For example, Missimer (1986) identifies twelve items in an argument structure so forcing his model to fit with Toulmin's five or six features would be a compromise. Hence, using Toulmin's model as a base for representation is again a problem.

To solve these problems, the Toulmin argument structure has been abandoned as the basis for the model of reasoning on which to build the software. Instead a lower level of representation is introduced. With this generic representation, any model, such as Toulmin's or Missimer's, or the five paragraph essay, can be constructed. Further, the structures of chains of reasoning can also be represented.

The basis of the new generic model is a set of **statements** from the domain of discourse. Statements may be specific and concern the details of a particular issue or they may be general and describe the conditions within which the issue is examined. Statements may be factual or they may identify values and beliefs. They may be unchallenged assumptions, proven data or contentious open questions. Any unit of information from the domain is considered a statement.

Statements may be identified as facts or claims. A **fact** is a statement which is accepted as a basis for argument; that is, the argument proceeds on the presumption that the fact is true. If a fact is to be challenged, it is challenged outside the current context. A **claim** is a statement which is meaningful in the domain of discourse but not necessarily accepted as true. The purpose of constructing a reasoned argument is to establish a claim.

A unit **argument** is defined to be a structure which organizes a set of facts in support of a claim. In the scope of the argument, the facts are accepted as true and the claim is established by the argument based on the facts. The acceptance of the claim depends on the acceptance of the facts and on the validity of the argument.

The argument is modeled as a directed graph in which statements are attached to **nodes**. To represent a particular form of argument, a particular graph structure, called a **strategy**, is used. A strategy specifies the number of nodes in the argument, their properties and the directed links between them. The properties of a node are described as its **role**. One role in the argument is the claim; other nodes have roles which require facts.

To apply an argument to a set of statements, the statements are associated with the nodes of the argument. The statement associated with the claim node is established by the organization of the other statements into the roles, providing the semantic content of the argument according to the specific strategy. (Toulmin's model is now represented as one strategy for the unit argument graph in which *grounds, warrant, backing, rebuttal* and *claim* are roles for the nodes[13].)

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[13]Modality is not represented as a node with a role. It is a property of the argument.

Any statement which is to be used as a fact in an argument must be true in the scope of the argument. When a statement is associated with the claim node in an argument, it becomes established and thereafter may be used as a fact in the scope of a different argument. In this way a sequence of arguments can be built. However, some beginning set of statements must be accepted as a basis. In effect these are the already agreed statements from which the reasoning begins and their validity must be established outside the current reasoning activity. Some examples would be the symptoms on which a diagnosis is based or the body of literature of an academic discipline. In the context of this reasoning process, these facts are validated by **support**. Support may be of many types, including citation or experiment but also assumption or value or belief or edict. The accepted forms of support are called **evidence**.

A **chain of reasoning** consists of arguments which are connected through claim/fact links. A **major claim** is a claim which is established as the ultimate (sink) claim in a chain of reasoning. Its establishment is presumably the original goal of the reasoning exercise.

The model of the chain of reasoning is a hierarchical systems model. The external connections to the surrounding environment (the domain of discourse) are of two types: the inflow of information is by way of the supports for the basic set of fact statements; the outflow is the major claim statement (established as fact by the chain of reasoning). When that statement is employed in some later reasoning process, this reasoning structure can be cited as the support for it as a fact.

The model can represent a multi-step argument but it can also represent a hierarchical view in which some arguments represent higher level strategies[14]. There is no requirement that the model become recursively deep - the claims at lower level are 'chunked' into facts for use in a strategy at the higher level.

Formally a chain of reasoning is represented as a tripartite, directed graph with vertices of three types (**supports, statements** and **arguments**), and directed edges of three types (**support⇒statement** or external validation, **statement⇒argument** or statement as fact and **argument⇒statement** or claim validation). Support vertices are source nodes. A statement vertex with outdegree 0 (not used in an argument) is a sink (major claim). See Figure 4.1.

To affirm that the generic model overcomes the problems described above with the Toulmin basic pattern of analysis, it was applied to reasoning strategies in texts on critical thinking and a broad range of other related domains. In all cases, the model proved adequate[15]. Considering that the unit argument and the chain of reasoning are both just directed graphs, this is not surprising.

The issue for the model is not its power of representation. The important question is how much analytic power has been traded off for representation. If we consider the kinds of analysis which we want to provide on a spectrum from structural/domain-

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[14]The five paragraph essay strategy is at a higher level than the argumentation strategies within a paragraph, for example.

[15]The software implementation was not always adequate. See the system evaluation in the next chapter.

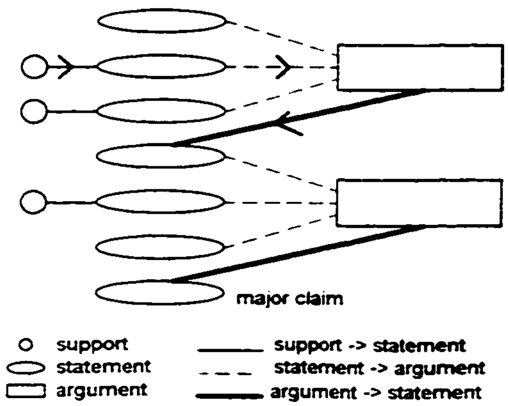

Figure 4.1: Tripartite graph representing a chain of reasoning.

independent to semantic/problem-specific, then we can describe exactly what is lost by moving to the generic system model.

The structure of the individual arguments and of the chain of reasoning are still subject to analysis as directed graphs. An argument is just a directed graph of nodes representing statements but a strategy is a particular graph with a role associated with each node. Toulmin's model can be represented in this way, as shown above.

In classifying arguments, Toulmin maintains the structure of his basic model of reasoning. The categorizing is based mainly on different types of warrants. Each different warrant has implications for the other roles in the strategy. When he discusses fallacies, he uses the basic roles and structure to describe the erroneous reasoning but the analysis he applies to reveal the errors is *not* structural. He describes heuristics for examining the content of the specific example in the context of the structural model.

For example, reasoning from generalization is one argument classification in which the **claim** is a statement that some population has a particular property based on the **grounds** of identifying the property in a sufficient sample from the population. He suggests that the external support for the grounds is crucial to acceptance of the claim so reasoning from generalization is vulnerable to 'hasty generalization' (e.g., too few or untypical samples).

In the language of the model here, the warning about the fallacy is associated with the role of warrant in a generalization strategy. Furthermore, the heuristic is applied to the content of the statement attached to the grounds. Hence any analytic power to be gained from the Toulmin model is not driven by structure. To the extent that the analysis is associated with, or even triggered by, the structure, the same capacity remains in the generic model. In fact, the introduction of the strategy, role and evidence constructs, separates these heuristics into their variant and invariant parts: the invariant part is the 'where' which is structural and the variant part is the 'what' which is specific to each particular strategy, role or evidence. The where features are associated with the basic model; the 'what' are incorporated as part of the creative design-in-use activity. See the system description in 4.2. for the implementation of the heuristic advice features.

4.1.2 Process

The original plan called for three stages to the process model: information gathering, organization, and analysis. This model has been maintained. Each stage is a different mode of activity and the modes are connected to represent the transition from one mode to another as in Figure 4.2.

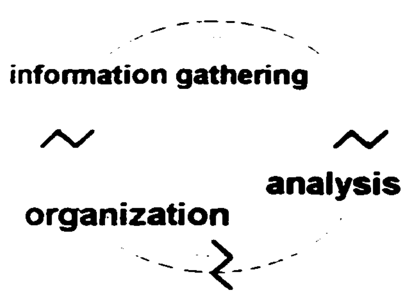

Figure 4.2: Three stages of the process model

The intent is to focus on the distinct features of each stage while allowing the process to pass easily and often from one to another. The four critical thinking activities (See section 3.1.1) are defined as processes using these modes - for the instructional and expressive user environments. (The creative user environments are defined in terms of the 'builder' capabilities. See section 4.2.4.)

4.1.2.1 Information Gathering

In the first mode of information gathering, the set of statements is created. The user is assembling the semantic content which will be manipulated to construct the chain of reasoning. The focus is on identifying and summarizing units of information. Some the user will enter at the keyboard; others may be cut from an existing document which is being analyzed. In creating a new chain of reasoning, the statement set is open, with adding or deleting statements always possible. In analyzing an existing chain of reasoning, the statement set is required to contain, at a minimum, the contents of the document and the focus of the user is on accurate and complete representation.

4.1.2.2 Organization Structuring

In the second mode, the statements are assembled into a chain of reasoning. In terms of the tripartite graph (Figure 4.1), the support and argument nodes must be added to the set of statement nodes forwarded from the information gathering mode. A support is always constructed in association with the statement it validates so the support node and the support⇒statement edge are created concurrently.

An argument is also constructed in association with the statement it supports as a claim - the argument node and argument⇒statement edge are constructed together. Once the node exists, the user can import other statements which are to be used in constructing the reasoning of the argument in support of the claim. This creates the statement⇒ argument edges of the graph.

The user is free to rearrange the statements in an argument so that, for example, a statement imported as a fact can be swapped with the claim statement. This has the effect of removing some edges in the graph and adding others.

A second class of activities in the organization structuring mode involves the templates (strategy templates for arguments and evidence templates for supports). These activities modify the properties of the nodes of the tripartite graph. For support nodes, evidence templates must be selected and information added. For example, if the support for a particular statement comes from the literature, then a *citation* evidence template could be selected and details of the reference included in the support node.

For argument nodes, a strategy template is chosen and the statements imported into the argument are associated with particular roles in the strategy. Clearly the strategy selected, and hence the roles to be filled, influence the requirements for statements. The structuring of the chain of reasoning and of the individual arguments is carried out concurrently and interdependently.

These first two modes of critical thinking, together with the structural model are sufficient to allow critical thinking activities to be portrayed quite concretely. For example, suppose we wish to describe and contrast the two productive critical thinking activities: (i) developing a reasoned argument in support of a claim and (ii) exploratory thinking in which a claim is developed.

(i) If we accept Toulmin's point that the time to construct a chain of reasoning is after becoming committed to the major claim, then the purpose is to establish the claim. Thus the activities of constructing a chain of arguments, grouping statements and selecting argument strategies are made with an eye to constructing the best case possible for the major claim. For example, confronted with a strategy which strongly argues for a claim but which does not fit well with the statements of fact, a user constructing a chain of reasoning might go in search of new information (statements) to fill out the argument strategy. Although the resulting chain of reasoning will be argued 'forward' from the facts to the major claim, the development of the reasoning takes place 'backwards.'

(ii) In the situation where a solution or major claim is sought through critical thinking, the development of the chain of reasoning tends to proceed more forward. The original conditions as expressed in the base of supported statements are more fixed and if a particular argument strategy does not fit well to a set of statements, the user is more likely to seek an alternate strategy that better fits the facts and that may lead to inferring a different claim.

4.1.2.3 Analysis

In the third mode of the process model, the chain of reasoning is examined to determine its strength as backing for the major claim. The analysis has structural and semantic components. The former, based on the graph structures of the chain of reasoning are automated and are treated like the constraints in a design problem. The semantic analysis is carried out by the user and is more like the aesthetic evaluation of design.

The structural analysis can determine incompleteness such as statements with no validation by support or argument, or arguments with roles unfilled by statements. It can also identify fallacies which are structural in nature such as begging the question which results in a cycle in the graph of reasoning. A third type of structural analysis produces warnings of allowable but poor structure such as unused statements or multiple major claims.

The semantic analysis addresses the statements, both as information units (for example: are they ambiguous?) and in relation to their roles in the arguments. These determinations must be made by the user through interpretation of the content, but the model provides for advice about criteria for making the determinations. Some advice is generic and is associated with the generic structures - statement, support and argument; other advice is specific to particular types (evidence, strategy and role) and is defined as part of the template in the creative 'builder' activity.

In the development of a chain of reasoning, the analysis mode provides feedback for formative evaluation. In the critique of an existing argument, it provides the basis for evaluation of the strength of the major claim.

4.2 System

The reasoning model has been implemented in Visual Basic. VB 2.0 was used for the first versions but the system was later upgraded to VB 3.0. As described later in this section, there are constraints imposed by this language which restrict the flexibility of the software. A switch to another programming language is planned for the next version.

Nonetheless, the easy manipulation of the high level structure and user interface in VB, makes it a good environment for prototyping.

4.2.1 System Design in Visual Basic

The program which implements the critical thinking model is named Peitho after a Greek goddess of persuasion. The reasoning model is implemented in a hyperstructure of Windows forms with the relations among the forms matching the structural organization of the model. The modes of the process model are explicitly represented in the program activities.

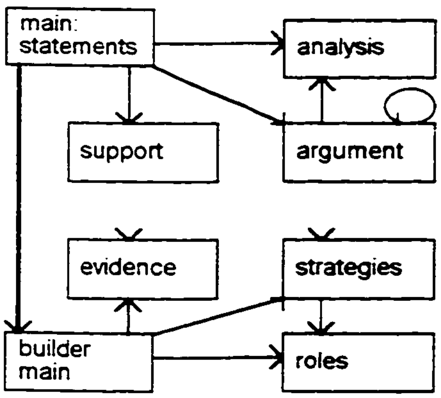

Figure 4.3: Forms in the Peitho software structure

Implicit in the model is the definition of strategy and evidence templates but no process for creating them is described. The program is extended with a set of activities for building these templates. The building activities would be used by the expert and the instructor in the two creative levels of activity to create templates. However, the organization of the program currently includes builder powers as an integral 'design-in-use' features of the software. The graph of major forms in Peitho is shown in Figure 4.3. The underlying data structures of Peitho match approximately the forms.

4.2.2 Features Related to the Purpose and the Model:

The base structure of Peitho is the set of statements. The information of each statement is contained in a **content** text field of arbitrary size and summarized in another short **summary** text field. The summary field provides a title of uniform size to include in a statement list in a VB control called a grid. When a particular statement title is highlighted in the grid, the corresponding detailed text is displayed.

To create a statement a user types into the content field and then copies or types into the summary field. If an existing document is being examined, that document can be opened concurrently with Peitho and passages of text can be copied and pasted into the statements.

Aside from the content and summary, each statement has fields which allow supports or arguments to be associated with it to establish it as a fact. It may also be connected to other arguments as a fact in the establishment of a claim. The statement and its connections are shown in Figure 4.4.

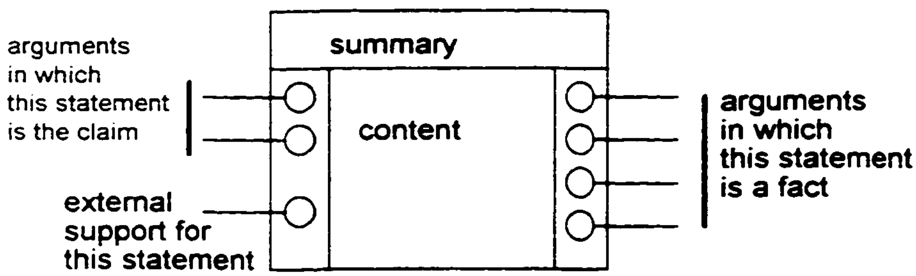

Figure 4.4: Fields of a statement form

The user manipulates the information in the set of statements in **information** mode. Statements may be added, deleted or revised. Initially, the statements are unconnected to arguments or supports but at later stages of the reasoning process, deleting a statement has implications for the argument structure which is maintained implicitly by Peitho.

In **organization** mode, the content and summary of the statements are fixed while the user builds the structure of the chain of reasoning. From the main form, the user selects one statement and then adds either a support or an argument which confirms it.

A support is added by opening a support form. There the user selects what kind of support is being invoked, for example a citation of a reference. She then adds comments detailing the specific support, for example the source referenced.

The connections of the underlying support data structure are represented in the accompanying Figure 4.5.

Figure 4.5: Connections to a support node

Adding an argument is a more complex and exploratory activity which begins in a similar way. An argument form is opened with the current statement identified as the claim of the argument. The user then must (i) drag other statements into the argument as facts, (ii) select a strategy for the argument, and (iii) associate the fact statements with the roles in the selected strategy. The complementary operations are also available to disconnect the facts from roles and to remove them from the argument. The strategy can also be replaced.

One implication of the exploratory activity is that the claim may be changed; that is, the statement may be disconnected from the claim role and another statement substituted for it. On the main form, each statement is annotated to show the supports and arguments which currently confirm it as a fact.

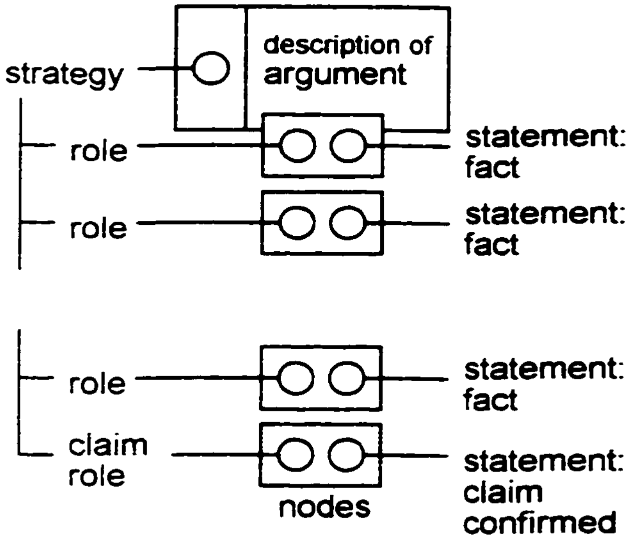

Figure 4.6: Argument with nodes showing connections to roles and statements

The connections of the underlying argument data structure are represented in Figure 4.6. The text field of the argument structure is available for description of the argument as a whole.

A chain of reasoning consists of a collection of arguments, supports and statements together with the links between them. The links are of three types as defined previously (Figure 4.1):

- a support establishes a statement,
- an argument establishes a statement,

and

- a statement contributes to an argument as a fact.

Consider a local view of the structure. From a particular argument form it is possible to follow links from the roles through the fact statements to the forms (argument or support) which establish them. Because the links are *many to many* connections, there may be a choice of which link to follow. For example, a role in an argument has a statement associated with it which is assumed to be true, a fact. To confirm that statement there may be one or more arguments (in which it is the claim) and/or external support. Alternately, a statement may contribute, as a fact, to more than one argument. See Figure 4.7.

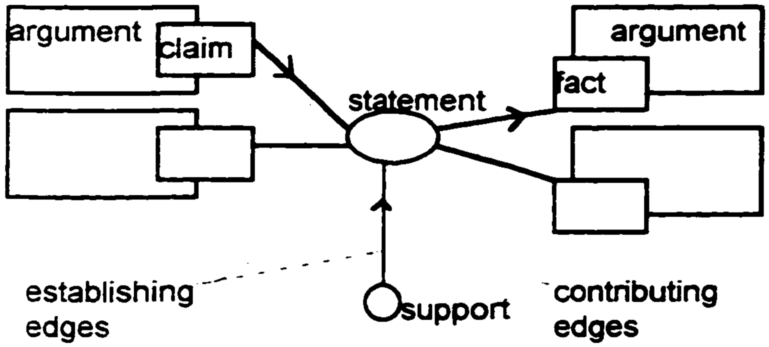

Figure 4.7: Edges associated with the statement node in a graph of a chain of reasoning

To summarize the global view of the chain of reasoning, the structure is a directed, tripartite graph in which the nodes are **statements**, or **arguments** or **supports** and the directed edges are either establishing edges from arguments to statements or supports to statements or contributing edges from statements to arguments. Supports are source nodes with indegree zero and a statement node with outdegree zero (sink) is, by definition, a major claim because it is not used as a fact in any further argument.

4.2.3 Provisions for Analysis and Critique of Arguments

Criticism has been defined to include analysis of the structure of a chain of reasoning, verification of the facts on which it is based and judgment of the fit of the facts to the structure.

In **analysis** mode, as in the other modes, the learner/user is in complete control of the criticism of the chain of reasoning. Peitho supports the user by organizing the activity and providing analysis and advice. The structural aspects of criticism are generic and syntactic and, hence, open to automated analysis whereas the aspects which require interpretation of the content of statements are more specific and subjective.

The analysis of the chain of reasoning is based on the graph created in the organization mode. Peitho can currently provide the following critical information:

- If more than one statement node is a sink, there are multiple major claims. This condition indicates a chain of reasoning which is not making one main point.

- If any of the (multiple) major claims is not established by an argument, then the statement is unconnected to the chain of reasoning and is superfluous: both unwarranted and unused.

- If the graph contains any cycles, the chain of reasoning contains a circular argument, the so-called 'begging the question' fallacy.

- If any statements which require confirmation have indegree zero, then the verification of the facts supporting the argument is incomplete[16].

By analysis of individual arguments, other critical information is revealed.

- If any particular role node has no statement associated with it, (i.e., the indegree of the argument is too small), then the basis of the argument is incomplete.

Beyond the generic structural features, the criticism of a chain of reasoning depends on the meaning of the statements. Whether or not a statement has a support form associated with it can be identified by analysis of the data structure, but the strength of the support is determined only by consideration of the type of evidence, the connection of the

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[16]Statements require verification if any of the fact roles they fill require verification. Some roles in certain strategies may require statements that are established and used only within the argument. These would not require establishment as facts. For example, some models of deduction require that the major premise be instantiated:

All men are mortal. Socrates is a man. Therefore Socrates is mortal.

is represented as

(i)	**$\forall x$: man(x) $\Rightarrow$ mortal(x)**	**(major premise; externally established fact)**
(ii)	**man(Socrates)**	**(minor premise; externally established fact)**
(iii)	**man(Socrates)$\Rightarrow$mortal(Socrates)**	**(established by substitution in (i))**
(iv)	**mortal(Socrates)**	**(claim of argument for 'export')**

The third statement is established within the argument and does not need external confirmation.

evidence to the statement and the acceptability of the evidence in the conventions of the discipline. Similarly, the meaning of statements must be examined to determine the strength of an argument or the fit of a statement to a role.

In these situations, the role of the program is to advise the user. Where should attention be focused? What questions should be asked? Some advice is generic and can be built into the program directly; other information is specific to the strategy, role and evidence types defined by the builder. Peitho accommodates both.

The model of advising is based on the source of advice and the situation for which advice is offered. The source may be either

- the Peitho system (generic), or
- the template builder (specific).

The situations are defined in terms of the underlying structure and process model of reasoning. Advice is associated with:

- statements,
- supports / evidence,
- nodes / roles,
- arguments / strategies, and
- chain of reasoning.

Table 4.1 shows the advice fields. The *System* field contains the generic advice and the *Builder* field contains advice provided by the builder of the strategy, role and evidence templates. The field labeled *Sys/Builder* is not visible to the user; it contains guidance for the builder in creating the corresponding builder fields.

Table 4.1: Peitho's advice structure

ADVICE/NOTES	System	Builder	Sys/Builder	Analysis
Strategies	√	√	√	
Particular Strategy		√		
Particular Argument				√
Roles	√	√	√	
Particular Role		√		
Particular Node				√
Evidence	√	√	√	
Particular Evidence		√		
Particular Support				√
Chain of Reasoning	√			
Particular Chain				√
Statements	√			
Particular Statement				√

The final column shows the *Analysis* fields which are associated with a particular project. These are available to the user to make notes about the chain of reasoning. For example, a user who is analyzing a chain of reasoning in order to refute it, will look for vulnerable points. Upon discovering one, she will not return to organization mode to fix it; instead she can make note of it in the appropriate analysis field.

At any time, the structure and analysis of a chain of reasoning can be summarized on the screen or printer in a linearized version. This summary serves many purposes:

- snapshot of the current progress of the analysis, to serve as a 'to do' list,

- introductory orientation for a new member of an analysis group, or
- outline for a draft of a written document to export to a word processor.

To make the summary more flexible, the user can select from a menu which features to include in the output. The basic content is a list of the statements but other items, from the roles to the analysis notes may also be included.

The summary is organized according to a spanning tree of the graph structure with the major claim at the root. The facts in the argument supporting the major claim are indented and, if they have supporting arguments, those facts are indented further.

Structural and analytic features can be added. See Table 4.2 for the latest version.

Table 4.2: Features which can be included in the linearized summary of an argument or chain of reasoning.

Features included	Description
Structural Parts	Identify claims of arguments
Role Names	Identify roles played by each statement in the argument strategy
Strategy Names	Identify the strategy type of each argument
Evidence Names	Identify the evidence type of each support
Critical Notes	Include notes added by user in analysis mode (when corresponding Structural Parts, Evidence Names, Strategy Names or Role Names is also selected)
Warnings	Include warnings generated by the structural analysis of the graph
Content Details	Include details behind each statement (and support information if Evidence Names is also selected)

Note that some features work in combination.

4.2.4 Building Templates: Creative Activity of Expert and Instructor

The expert or instructor uses the builder mode to prepare the templates which are employed in constructing a chain of reasoning. The forms for the strategy, role and evidence definition are organized in the same format. The creator selects the form, role say, from the builder form menu and then either selects or adds a particular role on the menu. That role is then edited to provide the title, content description and analysis advice as well as some housekeeping features such as colour. Defining evidence is essentially the same as defining a role. Strategies are created the same way but the editing also includes the selection and arrangement of roles in the graph. If a new role is required, it can be defined in the role selection process.

Once a set of templates is defined it can be saved in a file which is then available for use in instructional or expressive activity[17].

4.3 Exploration

To give a sense of how a learner uses Peitho, the following section contains a description of an exercise in which a poem is analyzed. After that, the instructor's interaction with the program is discussed.

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[17]In the organization of Peitho, the builder mode is just another part of the program accessible to any user. The learner who becomes an expert will have the builder mode for design-in-use to create individualized strategies. See section 3.3.

4.3.1 Extended Example Walkthrough: a Learner's Experience Analyzing a Short Text

This section contains a complete hypothetical example, in an environment with the following parameters:

User: a learner in an expressive activity

Domain of discourse: aesthetic

Type of activity: critique an existing chain of reasoning

To illustrate the learner's experience with Peitho, consider how a beginner could use the system to analyze a text. This fragment of a poem of Sappho in Figure 4.8 is one of the first examples in Walker and McClish (1991).

Toulmin (1979) suggests that there are three forums of argumentation in the arts. Working artists discuss technique; audiences discuss perception and interpretation, and historians discuss historic and aesthetic significance. Here we use Peitho in the second forum to develop an interpretation of the poem fragment.

Figure 4.8: Poem of Sappho

He is a god in my eyes--
the man who is allowed
to sit beside you--he

who listens intimately
to the sweet murmur of
your voice, the enticing

laughter that makes my own
heart beat fast. If I meet
you suddenly, I can't

speak--my tongue is broken;
a thin flame runs under
my skin; seeing nothing,

hearing only my own ears
drumming, I drip with sweat;
trembling shakes my body

and I turn paler than
dry grass. At such times

death isn't far from me.

As a subject of analysis, a poem is distinct in two relevant features. First, a poem typically uses language sparingly and is dense with concepts compared to some other document forms. Many of the statements are short enough to be listed directly rather than summarized. Second, a poem typically implies rather than expresses its thesis or major claim, so the reader must construct rather than identify it, much as she would do in discovering a major claim from data or solving a problem.

The user first isolates individual statements and creates the statement list in information mode. If the poem is in a file, this can be done by cutting and pasting into Peitho. The result is in Table 4.3.

	Table 4.3: Statements from poem of Sappho
1	He is a god in my eyes
2	The man is beside you
3	he listens intimately to your voice
4	your laughter makes my heart beat fast
5	meet suddenly -> I can't speak
6	my tongue is broken
7	my skin is inflamed
8	I am seeing nothing
9	hearing only my own ears drumming
10	I drip with sweat
11	trembling shakes my body
12	I turn paler than dry grass
13	death isn't far from me
14	
15	
16	

The user now switches to organization mode to begin to put together a consistent interpretation of the poem. Where to begin? There is no 'topic sentence' so the major claim of the piece is not explicit[18]. Suppose the user tentatively groups together the statements which all concern the man. This can be done by tentatively selecting one of them as a **claim** and creating an argument for it. '1 He is a god in my eyes' is a good choice as it is metaphoric while the others are more factual. The other statements about the man (2 and 3) are then dragged into the argument.

[18]Identifying a thesis or topic statement is not always easy for a beginner, even if it is present.

At this stage, the argument form has no strategy for framing the argument. It has only the claim identified and the list of 'facts'. To explore the strategies provided by the instructor, the user opens the strategy frame and looks at the menu of strategies. In this case the strategies are from Walker and McClish (1991) and are listed in Table 4.4 with the explanation the user sees while browsing.

From the descriptions, the learner decides to try 'For Analysis by Example' and this strategy is now displayed in the argument frame beside the list of statements.

The learner now experiments with the strategy by trying the statements in the various roles. To clarify the requirements for the roles, he can look at the role form and refer to the note describing a particular role. For example, the role 'Example Claim' has

Table 4.4: Argument strategies available to learner

For Analysis By Reasoning	Argument by 'logos' or reason. A claim is shown to follow from the 'structure of reality', i.e., from a set of accepted facts, by a strategy of reasoning which is also agreed.
For Analysis By Example	Support of a claim by demonstration of a special case where it is evident.
For Judgment	A judgment is an argument about how something should be evaluated. The thing judged must be defined before it can be evaluated.
For Policy	A decision is argued for, concerning a solution to an agreed problem.

the description, 'A claim about a specific case.'

Figure 4.9 shows the argument form as it might appear during the exploration. The statements have been attached to roles and the learner's attention is focused on the

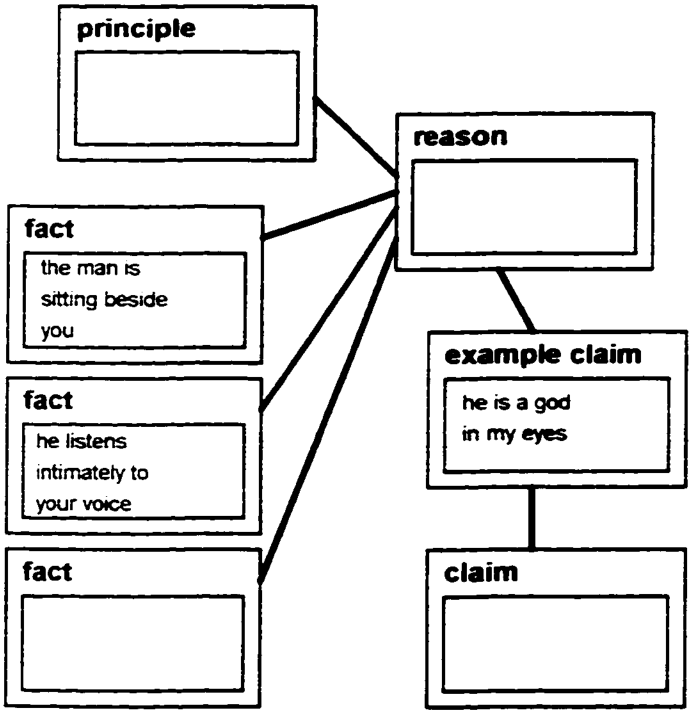

Figure 4.9: Argument form from the analysis of the Sappho poem

roles which are still unfilled. Note that some insight has already been gained - the learner has decided that the claim that 'he is a god in my eyes' has been changed to just an example claim supported by the two factual statements.

The learner might now focus on why the facts lead the author to the example claim. The Principle inferred from the metaphor might be that *gods have capabilities beyond human* and that leads to the Reason for the example claim: *the man appears to have accomplished something superhuman in sitting next to his love and listening her voice.*

These two statements have emerged from the exploration of the strategy and must be added to the list of statements (in information mode) if they are to be used in the strategy. There is no requirement that all roles be filled. If the user feels that the reasoning here is obvious enough to ignore, the roles may be left blank. Note that the third Fact node is unused in this argument.

Attention now focuses on the main claim of the argument: what is implied by this metaphoric example? Is the author envious or jealous of the man? Some claim like this should be evident and a statement can be added to the set of statements.

With the argument now structured, the learner switches to analysis mode to check for possible problems. On the argument form, the structure is temporarily frozen and analysis heuristics are presented: **Strategy**, **Elements**, and **Structural**. Looking at Strategy, the learner is advised as follows.

For Analysis by Example:

> This kind of argument is relatively weak: an example does not prove a general case; a counterexample can threaten it.
>
> An example is best used in parallel with an argument by reasoning, so it serves as an illustration.

The learner considers the caution and decides to record a reminder in the note window for later reflection:

> Is this argument too weak? Is there other support for a different interpretation?

Next, he selects the Elements activity which guides him to focus on the individual nodes of the argument, considering description and critical concerns of each role and how well the attached statements meet the requirements. For **Example Claim** he sees:

> Example Claim: The interpretation of a sample situation produces a sample claim which is generalized. Is the example claim valid? Is the example typical in the way it will be generalized?

The statement in this role is "He is a god in my eyes." He satisfies himself that it is based on the facts but he is not so sure that the general claim, "I am envious of him near you." is worded as well as it could be as a generalization. He records that concern in the note associated with the node.

Switching to the Structural analysis, the learner creates a linearized summary of the argument. By selecting various options in creating the summary, the learner gets different viewpoints on the structure of the strategy, including, for example, a warning that some of the roles are not filled by statements. He has already considered this point in constructing the argument and allows himself a smile of confidence. See Figure 4.10.

I am envious of him near you
He is a god in my eyes
The man is sitting beside you
he listens intimately to your voice
Warning: Basis fact missing for role Principle
Warning: Basis fact missing for role Fact
Warning: Basis fact missing for role Reason

Figure 4.10: Summary of an argument

The warning notes he'd made about the strategy and the roles also show up when he selects other options.

One argument is complete. The learner could return to the list of statements and try again the same approach of seeking a set of related statements and trying to arrange them in an argument. The ultimate result of this iterative process will be a complete chain of reasoning which represents the learner's interpretation of the poem. Clearly there are many points at which the exercise could take a different path - this is an expressive activity - but a typical result might involve two more arguments by the strategy 'For Analysis by Example', both establishing the claim that the poet is flustered in the presence of the woman. One argument is based on her inability to talk with the woman and the other on her strong physical reaction that makes her feel she is near death.

To complete the structure, her envy of the man and her flustered state (the two newly established claims) are grounds for a final argument for the major claim of the piece: she longs to be with this woman.

your laughter makes my heart beat fast
Warning: this statement is unused
I long to be near you
    I am envious of him near you
        He is a god in my eyes
        The man is sitting beside you
        he listens intimately to your voice
    I am flustered when near you
        meet suddenly -> can't speak
        my tongue is broken
        hearing only my own ears drumming
        seeing nothing
        ---
        death isn't far from me
        I turn paler than dry grass
        trembling shakes my body
        I drip with sweat
        skin inflamed
        Warning: no role for fact in strategy
Warning: there are multiple claims.

Figure 4.11: Linearized graph of poem with warnings

The statement list now includes the statements inferred by the learner (14, 15, 16 of Table 4.5). In organization mode, the list also identifies the justification for each statement, if any. **R** indicates an external support reference (in this case, just the facts as the poet tells them) and **A** indicates an argument. Note that statement 15, the claim of being flustered in the woman's presence is supported by two arguments. Also note that some statements have no justification.

Table 4.5: Statements including those added by learner during investigation

1	He is a god in my eyes	
2	The man is beside you	R
3	he listens intimately to your voice	R
4	your laughter makes my heart beat fast	
5	meet suddenly -> I can't speak	
6	my tongue is broken	R
7	my skin is inflamed	R
8	I am seeing nothing	R
9	hearing only my own ears drumming	R
10	I drip with sweat	R
11	trembling shakes my body	R
12	I turn paler than dry grass	R
13	death isn't far from me	
14	I am envious of him near you	A
15	I am flustered when near you	AA
16	I long to be near you	A

To get a better overview of the chain of reasoning, the learner can advance to analysis mode at the level of the entire chain of reasoning and generate a linearized view of the statements organized into all the arguments. In order to get help with analyzing the chain of reasoning, he asks for warnings to be included. See Figure 4.11.

I long to be near you
    I am envious of him near you
        He is a god in my eyes
        The man is sitting beside you
        he listens intimately to your voice
    I am flustered when near you
        meet suddenly -> can't speak
        my tongue is broken
        hearing only my own ears drumming
        seeing nothing
        ----
        death isn't far from me
        I turn paler than dry grass
        trembling shakes my body
        I drip with sweat
        skin inflamed
your laughter makes my heart beat fast

Figure 4.12: Final linearized graph

Three warnings have appeared[19]. Notice that 'your laughter makes my hear beat fast' appears first and at the left margin with the major claim. As the warning indicates, the statement was not used in any arguments and hence is outside the chain of reasoning which has been constructed. The warning at the end is generated by the same statement because there are two statements which are not employed in arguments and are hence interpreted as major claims. The learner attends to the statement causing the problem. It is not connected directly to the claim of envy for the young man; neither is it describing her state when meeting the woman. Nonetheless, it does support the major claim. The learner considers adding another argument for a claim of 'hearing you excites me' but there are no other facts to add, so he decides to add the statement directly to the argument for the major claim[20].

The learner again returns to analysis mode and looks at the linearized view. Without warnings, the view now shows the complete chain of reasoning. (Figure 4.12)

The learner is now satisfied with the structure and proceeds with further analysis. The analysis mode is comprised of three activities. As well as the **Structure**, the learner is

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[19]Other warnings are possible when more options are selected concurrently for the linearized view.

[20]The warning after 'skin inflamed' indicates that the statement has been included on an argument form but does not play any role. This is an artifact of Peitho structure. See chapter 5.

guided to examine the individual **Statements** and the **Context** in which the entire argument takes place. He checks the individual statements, following the simple advice:

The individual statements must be clear and unambiguous.

In checking context, he is advised to consider these questions:

1. How formal is the reasoning? Are the steps prescribed?
2. How precise are the arguments?
3. What is the means of resolution? Is the argument aimed at an adversarial decision, a pragmatic decision, a compromise, a consistent interpretation or establishment of truth?
4. What is the goal of the chain of reasoning? What is at stake?

He thinks about the domain. He is contemplating a poem, not as another poet concerned with craft or as an historian steeped in the times of its composition but as a critical reader trying to interpret the poet's words. There is no need to find a 'right' interpretation, no impetus to convince another reader that his depiction is the only one. He rereads the poem and finds nothing which conflicts with his interpretation of longing for love. This seems to satisfy the warning he read earlier about the weakness of the argument by example. In this domain, the concern is not justified.

The learner exports a copy of the linearized argument to his word-processing program and uses the outline to begin writing an interpretation of Sappho's poem.

4.3.2 Example Walkthrough: an Instructor's Experience Designing Templates for a Specific Reasoning Model

This section contains an example, in an environment with the following parameters:

User: an instructor in a creative activity

Domain of discourse: aesthetic

Type of activity: any

To create an environment for a learner, an instructor is responsible for creating the set of templates that the learner will have available, templates for evidence and strategies. Creating strategy templates implies defining the roles within them.

The instructor uses the same forms for creating evidence and strategy types as the learner uses for selecting them. The only difference is that the instructor has editing capability. In the evidence form, the instructor is responsible for providing general critical guidance about using the set of evidence types as well as specific information about the individual evidence choices. Guidelines for writing critiques are available to the instructor while composing this material. Table 4.6 shows the information which must be provided.

The strategy form is more complex. The instructor must provide descriptions for a strategy analogous to those for the evidence but must also create the graphic structure of the argument. This involves creating and placing the required number of nodes and connecting edges. See Table 4.7.

For each of the nodes there must also be a role assigned. Roles are created either before or during the design of a strategy on a form which is identical in format to the evidence form. For each role, the instructor provides information analogous to that of an evidence type. Roles are then associated with nodes on the strategy form where they are identified by name and colour. In any template set, the roles tend to show up on several strategy graphs.

It is also on the strategy form that the instructor gives an overview of the set of strategies and provides guidelines for analyzing the complete chain of reasoning.

In summary, the activities on the strategy form involve this overview and the activities specific to each strategy.

Table 4.6: Information in an evidence template	
Feature	Example
Name	Testimony
Description	Support by statement of an outside source - may support a specific fact or a principle.
Critique	Testimony: Testimony is vulnerable to an 'appeal to authority' criticism if the testifier is not credible in the domain of the claim being supported or if the testifier may have other motivation.
Colour	yellow

4.3.3 Application: Instructional Design of a Sequence of Templates for Learning Critical Thinking according to a Particular Author

The Sappho love poem was interpreted using templates based on the introductory chapters of Walker and McClish (1991) where the poem is reproduced as an exercise. In these templates, four strategies and eight kinds of external evidence were defined. To design the strategies, ten roles including *claim* were required.

The authors' discussion of argument is short and really only intended to set up the collected readings. Nonetheless, they introduce a framework and terminology which is used throughout the text. The Peitho templates capture this intent but they also reflect the limitations. Like the discussion in the book, the set of templates is effective for an experienced reader who only needs to become familiar with their particular model; however, for a beginner, the descriptions, and the set of templates, would be insufficient.

To create an environment for effective learning, the instructor can do much more with the Peitho software. The program is designed on the model of Increasingly Complex Microworlds (ICMs) originally conceived by Seymour Papert for LOGO. Each

Table 4.7: Information on a strategy template	
Feature	**Example**
Name	For Analysis By Example
Description	Support of a claim by demonstration of a special case where it is evident.
Select nodes	7 nodes in this strategy
Locate nodes	.
Draw edges	6
Select node roles[21]	e.g., 'Example Claim'
Critique	This kind of argument is relatively weak: an example does not prove a general case; a counterexample can threaten it. An example is best used in parallel with an argument by reasoning, so it serves as an illustration.

microworld is defined as a set of templates with later microworlds offering more complex and numerous alternatives than earlier ones. The problems posed can grow correspondingly in size and complexity from instructional one step arguments based on a few statements to complex chains of reasoning based on scores of statements for expressive activities.

Toulmin, Rieke and Janik (1979) spend several chapters developing a "basic pattern of reasoning", introducing the elements (roles), one by one. At each stage, they provide exercises based on the evolving strategy model. This approach is readily represented in a sequence of microworlds in Peitho. The 'grounds' and 'backing'

[21] Implies creating roles on role form if necessary.

elements lead to the notion of outside support and the use of support templates. In each microworld, only one argument strategy is available so the learner is not yet faced with that choice, and, so far, only needs the information gathering and organizing modes.

Following definition of the basic pattern of reasoning, these authors introduce the concepts of criticism and fallacious reasoning. In Peitho, this evolution is represented by introduction of the analysis mode in which these features are represented.

The final section of the Toulmin book covers the distinct strategies of reasoning and their application in particular domains of discourse such as science and law. At this point the choice of strategies as templates shows up in Peitho microworlds.

The weakness of the Toulmin text is that it has little to say explicitly about chains of reasoning. As the basic pattern is developed, the example passages become longer and more complex but there is no guidance on how the steps are combined. Other sources pay more attention to this matter. As a result, the set of strategy templates will include some strategies intended for use 'later' or 'higher' in the chain of reasoning than others. Walker and McClish, for example, specify three goals of argument - decision, judgment and analysis (establishment of facts or conditions) with judgments based on analysis and decisions based on judgments and analysis.

In the Sappho example, the goal is only to understand the poem. Only 'analysis' templates are used. The assignment could be pushed further to an evaluation (involving a judgment template presumably) in which the learner would state some opinion about the poem and argue in support of it.

A final feature which the instructor may include in the sequence of ICMs is access to the **builder** category so the learner (now self-reliant in expressive activity as an expert) may extend the set of templates and use Peitho on the creative level.

Table 4.8: Control features available to instructor

Feature (Software)	Range
Evidence Templates	0 (ignore support) to many
Strategy Templates	1 (default strategy) to many
Strategy Complexity	2 roles to many
Modes	information, structure, analysis
Template Builder	no, yes
Feature (Problem)	**Range**
Statements	few to many
Chains of Reasoning	one step, sequence, hierarchy
Type of Reasoning	support of a claim, plausible reasoning, analysis & criticism, dialogue

The features which the instructor has available in developing a sequence of ICMs is summarized in Table 4.8.

4.4 An experimental test of Peitho

The final step of building the Peitho prototype was testing the model and, to a lesser extent the design and implementation, of the experimental system. An evaluation by a connoisseur of the instruction of critical thinking was undertaken with the participation of Dr. Lance Odland, who was concurrently teaching PHIL 2505 - *Straight Thinking and Argument* in the philosophy department of Laurentian University.

4.4.1 Purpose

This connoisseur evaluation was conducted as a summative evaluation of the software prototype. The purpose was to verify the usefulness of the model underlying

Peitho as a tool supporting critical argument and the learning of critical argument. This purpose was operationalized in these five questions:

1. How well does Peitho support the representation of models of critical thinking and argument?
2. How well does Peitho support the representation of a critical argument in the form of a particular model?
3. How well does Peitho support the design and development of a model of critical thinking and argument?
4. How well does Peitho support the development of a critical argument in the form of a particular model?
5. How, and how well, does Peitho support an instructor's presentation [and a student's learning] of a particular model of critical thinking and argument?

Questions 1 and 2 address the sufficiency of the representational power of the system. These are minimum requirements. Questions 3 and 4 consider whether there is any advantage for a user, beginner or expert, to using the system. The final question concerns Peitho as an educational environment.

The kind of answer to expect for the final question is based on the format of Peitho. It is a tool and it has the obvious characteristics of a tool. It is participatory with the user taking an active and controlling role; it concretises and scaffolds the user's execution of the task of critical thinking. On the contrary, it suffers potentially from the well known plateauing effects of tool use: learners in control of their own development are inclined to stop exploring the tool and the underlying concepts at some minimally productive level unless guided to advance. Peitho has been designed to allow this guidance to be built in by an instructor.[22]

However the design is generic; it has not been based on particular issues or problems in the teaching of reasoning and critical thinking. Hence, the answers to the final question in the evaluation are extremely important. If Peitho doesn't show potential for helping students through some of the difficulties they currently encounter, then it hasn't much usefulness as educational technology. In the absence of an experiment with students, the answers must come from the instructor evaluator and his opinion of where the software would be useful.

Because the project involves software as well as a theoretical model, the summative evaluation also considered some design issues. On the other hand, although some implementation problems with the software were identified, they are not considered in the analysis of the connoisseur evaluation.

4.4.2 Methodology

There was a significant constraint on the summative evaluation which limited the kind of study which could be conducted and, hence, the strength of the claims for validity. Peitho completely implemented the model proposed but the interface was not developed to a level of convenience for users. The results of any experimentation would be confounded the clumsy and inconsistent interaction which would impede learning and using the software. An experiment in all user categories was just not warranted. In particular, results with learners, trying to master critical thinking and a flawed software interface at the same time, would be unreliable.

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[22]See Table 4.8.

Instead, the study was undertaken with an instructor. This allowed all the questions to be addressed, either directly or indirectly. The instructor could speak from experience as a user of all aspects of the system and could offer an informed opinion concerning the use of Peitho by a learner. While the crudeness of the interface would still be an issue for an instructor learning the system, at least he would not be trying to learn critical thinking at the same time. Clearly, an opinion of an instructor cannot carry the weight of an experiment with learners in establishing the validity of the model. The claim of support cannot be as compelling. Every effort was made to corroborate the instructor's opinion[23] and make the claims of validity as strong as possible under the constraint.

This connoisseur evaluation can be located in the environment of parameters:

User: an instructor in a creative activity

Domain of discourse: any

Type of activity: analysis and criticism

We agreed to use the textbook from the course Dr. Odland was teaching (Copi and Cohen, 1992) as the basis for the study. This text begins with informal reasoning which is exactly where Peitho is aimed. It is however a logic text so representing the later material would test the boundaries of Peitho's capability.

The study was conducted over several sessions of forty-five to ninety minutes from November 1995 to March 1996. The first sessions were occupied with training on Peitho. Thereafter, Dr. Odland built template sets in Peitho and used them to analyze passages from exercises in the text.

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[23]A 'text book' analysis was done in parallel, to see if the same issues emerged as from the Peitho experimentation. See 4.4.4.2.

4.4.3 Conducting the study

The study was conducted as planned, though some sessions were rescheduled. The times and topics are listed in Table 4.9.

At the orientation sessions, I participated fully to train Dr. Odland in the use of the software. In later sessions, I only observed except to answer technical questions concerning the operation of Peitho. At all sessions I wrote my impressions as Eisner's connoisseur observer. In some sessions, issues arose which led us into fruitful discussion after the computer-based activity. The essence of these discussion is also in my notes.

At the end of the study, Dr. Odland, as the connoisseur of teaching critical thinking, wrote his impressions of the educational potential of Peitho.

Table 4.9: Schedule of connoisseur evaluation sessions (1995-6)

Date	Activity
Nov. 3	Meeting - Plan connoisseur evaluation
Nov. 15	Training - Demonstration
Nov. 22	Training - Using an existing chain of argument
Dec. 6	Training - Creation of chain of argument
Dec. 20	Training - Builder environment
Jan. 15	Study - Building informal reasoning system
Jan. 17	Study - Using informal reasoning system
Jan. 24	Study - Discussion
Jan. 31	Study - Informal reasoning structures
Feb. 7	Study - Informal reasoning examples
Feb. 14	Study - Informal reasoning with deductive example
Feb. 28	Study - Informal reasoning with deductive example
Mar. 6	Study - Deductive system examples
Mar. 13	Study - Deductive reasoning example

Table 4.10: Sources of Evidence	
	textbook curriculum
√	textbook exercises
√	Peitho files
√	session observation notes
√	instructor's evaluation
√	handwritten planning notes
√	transcribed in Appendix C

Aside from these written documents, the main sources of evidence are (i) the Copi and Cohen textbook for curriculum and exercises, (ii) the Peitho files created during the sessions and (iii) the hand-written notes made by Dr. Odland in planning his work with Peitho or in follow-up discussion with me. These items are listed in Table 4.10. Except for the curriculum content of the Copi text, all evidence has been transcribed or photocopied, organized by session date, and included as Appendix C.

4.4.4 Analysis

4.4.4.1 Problems with the study.

1. In the course of the study, some activities did not proceed as planned. The time allotted was insufficient so the various models investigated were not all implemented to completion. As a result, almost no experience was gained with analysis of chains of reasoning based on the textual content of the advice/notes feature (Table 4.1)[24].

This missing experience was partially offset by the added insight into the functioning of the interface but this information is primarily formative.

2. In his final reflections, Dr. Odland stated that he should have had a hard copy description of Peitho available to better appreciate the 'interconnections between the

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[24]The linearized structure of the chains of reasoning was thoroughly investigated.

various "levels"...'[25] Hence, he only saw in retrospect some instructional aspects of Peitho which he had not appreciated at the time. Dr. Odland had read relevant passages from the first draft of the thesis document in preparation for the training sessions but I should have prepared a reference document for his use.

4.4.4.2 Analysis strategy

The most important result from the connoisseur evaluation is the answer to question five concerning the usefulness of the Peitho system for learning. The answer to this question is built on the first four questions but rests ultimately on the opinion of Dr. Odland.

The validation of his views is an issue. He is, without question, the connoisseur of critical thinking and the expert instructor. However, his experience with Peitho may or may not have provided him an adequate picture of the system's capability, especially in light of the concerns described above regarding a lack of hard copy documentation.

To show that his opinion of the software is well-grounded, the analysis first focuses on validating the answers to the first four questions. This provides support for the answer to question five in two important ways.

- The establishment of Peitho as a representationally sufficient and supportive environment for critical thinking provides the *theoretical* grounds for the claim addressed in the fifth question.
- The capacity of the study to draw out insights about the first four questions lends credibility to the conclusions about the last question.

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[25] See the appendix for the text of Dr. Odland's *instructor's evaluation*.

Ideally, the way to confirm the study's validity concerning the first four questions would be to reproduce the results. I have done this by acting as system expert and analyzing the Copi and Cohen text in the same way as I analyzed many other sources on critical thinking during earlier cycles of development. The results of this analysis provide a control for the pilot study.

I analyzed the Copi and Cohen model of critical thinking for compatibility with the Peitho model [questions one and two]. This established where this text fit relative to the critical thinking models tested in earlier cycles. Chapter one on informal reasoning I expected would be quite similar whereas the section on deductive reasoning would be unique. I also considered what insights Peitho provided into the model of critical thinking in the text [question three] and the extent to which Peitho supported the analysis of arguments in the manner prescribed by the authors [question four].

This ideal textbook analysis formed the control for the analysis of the experimental use of Peitho by Dr. Odland. If the two approaches produced similar impressions of the usefulness of Peitho with this text, these conclusions would be confirmed and this would give some reason to accept the further conclusions concerning the usefulness of Peitho for instruction.

4.4.4.3 Analysis of the Textbook: Copi and Cohen

The Copi and Cohen text is a book on logic. It introduces informal reasoning, then analyzes the role of language in presenting arguments before proceeding to the formal development of deductive and inductive logic.

I tested the applicability of Peitho to represent the informal reasoning of the first chapter then applied it again to deductive reasoning. This is a more severe test as Peitho is based on a rhetorical model. I did not test the usefulness of the system in studying the role of language. This would have involved the advice structure extensively and the time available did not allow the instructor to achieve mastery of these aspects of Peitho. Deductive reasoning was selected over inductive for further testing of the structural aspects of Peitho as it appeared to offer the greater challenge.

Informal reasoning model of Copi and Cohen

Chapter one of Copi and Cohen introduces the basic notions of reasoning, beginning with a classically structured definition of logic. The terms *proposition*, *premise* and *conclusion* are introduced and these correspond directly to the statement, fact and claim objects of Peitho. The definition of *argument*: "*any group of propositions of which one is claimed to follow from the others, which are regarded as providing support or grounds for the truth of that one*" Copi and Cohen, p.5), is in complete agreement with the usage of that term in Peitho.

The inferential strategy of an argument is developed incrementally. The first model involves one premise and one conclusion, easily modeled in Peitho. The number of premises is then increased without reference to any internal structure to the argument. Here again, Peitho could model the unstructured argument but the first difficulty appears. The current inflexibility of the strategy structure would require separate strategies to be defined for arguments with one premise, two premises, three, four or more, supporting the conclusion.

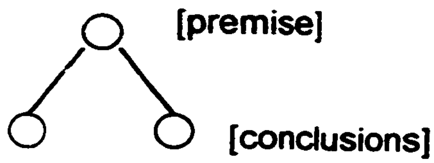
In discussing tactics for recognizing what role(s) a statement plays, the authors introduce 'conclusion indicators' such as *therefore* and 'premise indicators' like *since*. The description fails to clarify that these are structural rather than content features. As discussed later, the instructor was temporarily led to treat these as roles, like premise and conclusion. This is exactly the inconsistency identified in Toulmin's modal qualifiers.

The authors continue to develop the structure of argument by elaborating the concept of proposition in the premise role. They first distinguish between propositions which are part of the argument and others -- *explanations* -- which provide context for understanding premises or conclusion. These latter propositions recall Toulmin's notion of backing. While Copi and Cohen suggest that explanations are not part of arguments, they would seem to be important at least in definitions, and in backing as Toulmin defines it. In Peitho, they could be defined by a role, and supporting notes in the advice structure could guide learners in deciding which propositions fit that role. If explanations are less central to the argument structure, they are expressed in Peitho as external support in evidence types.

The next step introduces the distinction between what Toulmin would call grounds and warrants. This is begun by defining compound propositions and then categorizing them in a manner foretelling the logical emphasis of the text. *Conjunctions* are distinguished, as decomposable into their base propositions, from *disjunctive* and *conditional* propositions whose components do not stand alone.

The authors do not take this opportunity to discuss any argument strategies, even the obvious Modus Ponens. That might have provided better support for their next topic: the possibility of unstated propositions is introduced with the definition of enthymemes. Peitho is ideally suited to recognizing missing propositions because argument strategies will display empty roles. However, there are problems with applying that approach as they have not yet defined any conceptual link between the types of proposition and the roles of premise and conclusion[26]. In fact they show a diagram with missing components dotted in but there is no justification other than 'context' that something should have been there.[27]

Multi-argument passages are developed from the basic notion of premise and conclusion. The first extension is a confusing model allowing two conclusions from a single premise. The text states that, in fact, two arguments are defined but the accompanying diagram doesn't support this statement:



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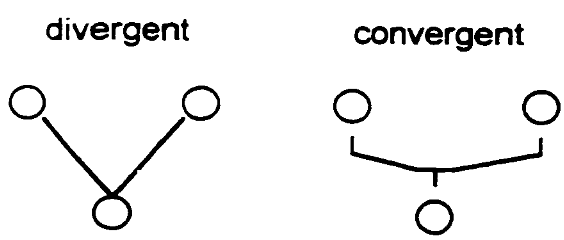
[26]The opportunity was there. Premises had earlier been defined to support a conclusion either *independently* or *cooperatively* in what was defined as *divergent* or *convergent* arguments.



In Peitho this would be a distinction between one supporting argument with two facts and two arguments supporting the same claim. Copi and Cohen explicitly state their contention: one claim means one argument.

[27]For example, one illustration of enthymeme (Copi and Cohen, p.33) is: "If that's artistic masterpiece, my name is Leonardo daVinci." As they state, there is an assumed premise (I am not Leonardo daVinci) and conclusion (That isn't great art). Without structure in the argument strategy, there is no guidance to the missing propositions but a Modus Tollens strategy makes them evident.

This situation would be represented more clearly in Peitho where the three statements would be listed then two arguments defined with the one supporting statement identified as the premise in each argument.

The potential for a proposition to play multiple roles (conclusion and premise) introduces the idea of a chain of reasoning. This approach is completely consistent with the Peitho model. All the concepts for chains of reasoning introduced in the text fit Peitho. Wherever multiple conclusions arise, the same substitution, of multiple arguments from the same facts, is made.

The subsequent section of the introductory chapter discusses deductive and inductive argument. In their definition of the difference between the two, Copi and Cohen describe the general and specific nature of the conclusions of the two types but they also claim that a specific argument is inductive if it is not certain. This view would not be widely supported but more importantly for a textbook, it confounds a *structure* categorization with a *content*-based categorization. The example argument[28] is an analogy. It is better understood as an enthymematic induction (in the stricter sense of generalization) with implied conclusion[29] followed by an enthymematic deduction with the same statement as an implied premise. Use of structured argument strategies helps to make this clear.

After that, they discuss truth and validity. This could be the basis for a test of the analytic support features of Peitho but was not included in this study.

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[28]Hitler was a dictator and was ruthless.
Stalin was a dictator and was ruthless.
Castro is a dictator.
Therefore Castro is probably ruthless.

[29]All dictators are ruthless.

The final section discusses problem solving, i.e., argument construction rather than reconstruction. Again, this section was not considered in the study.

Deductive reasoning in Copi and Cohen

The presentation of deductive reasoning is based on a set of rules of inference and a set of rules of replacement (tautologies). The particular sets employed in the text are listed in Appendix B. If Peitho were to support this part of the text, they would have to be represented.

Of course, these rules and tautologies are established foundations of deductive logic so there is no question of showing up weaknesses in the model. Rather, the attempt to implement them in Peitho challenges the capacity of the software and the model behind it. Because Peitho is based on rhetorical rather than logical precepts, it does not support the structure-based reasoning that deduction requires.

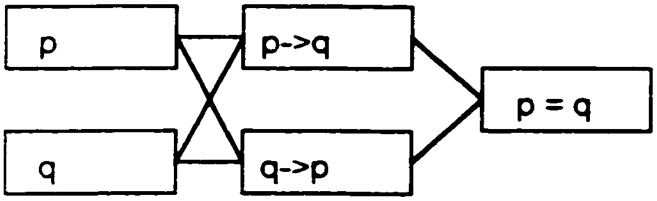
The rules in the table were implemented as Peitho strategies based on twelve roles. The rules of inference (1 - 9 in Appendix B) caused no structural problems but the tautologies did.

First, the substitutions are applicable in either direction so this would mean, in a Peitho strategy, the claim role and supporting roles might be reversed depending on the substitution required in a particular chain of argument. For example, using the Material Implication rule,

$$(p \supset q) \equiv (\sim p \vee q)$$

in one case, the claim might be $(\sim p \vee q)$ based on $(p \supset q)$ while in another, the claim might be $(p \supset q)$ based on $(\sim p \vee q)$. This has been solved by defining a different rule for substitution in each direction, producing a comprehensive but unwieldy set of 32 substitution rules instead of 16.

Figure 4.13: Material Equivalence using atomic propositions



The second problem is more serious. The results of substitutions are logical expressions but so are the premises or 'facts' on which they are based. Copi and Cohen had introduced these in chapter one as compound propositions.

One approach is to consider the basic propositions of the expressions (p, q, ..) together with components of one expression as supporting roles while the other expression is the claim role. This approach is straightforward for some tautologies, Material Equivalence for example:

$$(p \equiv q) \equiv [(p \supset q) \bullet (q \supset p)]$$

in the direction establishing the equivalence ($p \equiv q$). See Figure 4.13.

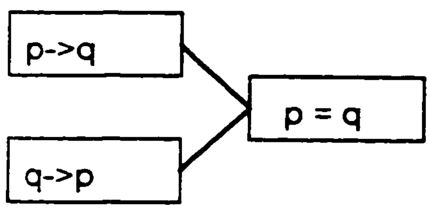
This can be interpreted as a strategy for establishing the equivalence of two propositions, however it does not bear close examination. To apply it, the truth values of p and q would have to be known so there would be no point to establishing the intermediate implication roles. This is not surprising as tautologies do not advance an argument but only restructure it.

Another approach is to consider tautologies as ways to establish compound propositions from other ones. Compared to the approach above, this one has no basic propositions[30] as shown in Figure 4.14. For the Material Equivalence example, it is the implications which must have external support.

In this approach, the tautological strategies would appear as support for warrants. For example, if an argument depended on an equivalence warrant, the above tautology could decompose the equivalence backwards into two implication warrants, each of which had secure backing.

This example suggests the potential for representing and using the tautologies but the case should not be overstated. Without, at very least, some kind of coding of links within argument strategies to identify negation, disjunctions and implication, the representation of other decompositions is not very enlightening. This design change was hinted at earlier, in the strategy of argument by dilemma which establishes a claim independent of the truth of some of its grounds. Even Toulmin's role of rebuttal would be better captured with a negation link available.

Figure 4.14: Material Equivalence with hypothetical propositions only



Furthermore, this approach to tautologies requires that each expression which is one side of a tautology be defined as a role so it can be the claim of some particular strategy. As extensions to a rhetorically oriented system, many of these would have questionable value (Assoc. for example), but they would be required if Peitho were actually to represent formal deductive arguments.

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[30]The most primitive of the tautologies (D.N. and Taut.) are the only ones which involve basic non-decomposable propositions directly.

A third approach implies implementation changes as well as the design extension defined above. Tautologies could be considered different views of the same compound proposition. They would not be defined as strategies; rather, each role which is one side of a tautology would be 'clickable' to change views. As a simple example, in Modus Ponens, the implication role, $(p \supset q)$, could be clicked through $(\sim p \vee q)$ and $(\sim q \supset \sim p)$ at least. This would enhance the exploratory convenience and reduce the size of the strategy set.

These extensions to the Peitho model are predicated on the precedence of *representational* power over *analytic* power. There is no implication that coded links or multi-view roles would include deep representation. They would be notational tools for expert users and instructors, not the beginnings of an expert deductive reasoning system. If some validity checking were possible -- as circular reasoning and unused statements are now recognized in Peitho -- that would be useful. However, these would be seen as constraints on a creative design system rather than the rules of an autonomous reasoning system.

Summary of the text analysis

Only points where Peitho is weak or where it reveals a weakness in the critical thinking model in the text are included.

1. Peitho would be inflexible in representing the general model of an argument as a conclusion based on a varying number of propositions. The number of nodes in a particular strategy is fixed. The user could be given the power to change the number of propositions but this would conflict with the support a fixed strategy structure gives to recognizing missing statements. Making some nodes of an argument replicable at the builder's discretion could solve this conflict.

2. Proposition indicators are not peers of the propositions they indicate. This content/structure distinction is not clear in the text but is concrete in Peitho.

3. Explanations are not outside the realm of argument as the authors indicate. Their distinctive features are clearly representable within the model of critical thinking of Peitho.

4. Enthymemes are poorly introduced in the text within an unstructured argument model. Peitho makes missing statements evident in a strategy.

5. Peitho provides better representation for the agreed declaration that an argument only has one claim. Conversely, based on the notion of divergent argument, the authors take the position that a claim can only rest on one argument. This conflicts with the Peitho many-to-one model.

6. Representing tautologies is clumsy in Peitho. At a minimum, builder-definable properties for the links of a strategy are required along with implementation changes.

4.4.4.4 Analysis of the Pilot Study

The study centred on two aspects of the course based on Copi and Cohen: informal reasoning and deductive reasoning. Dr. Odland first experimented with the informal model, building and rebuilding it in Peitho while applying it to several passages taken from exercises in the text. He finished this stage by using the informal model to analyze a passage from the section of the text on deductive reasoning. He then tried building chains of deductive reasoning in Peitho. Again, a cyclic approach was used. The training sessions are not included in the following description.

Pilot: informal reasoning

- At the first session on January 15, Dr. Odland created an informal reasoning environment with a set of eight roles and four strategies. No evidence templates were defined and no analysis notes were added[31].

Roles:	premise	conclusion	sub-conclusion
	explanation		
	premise indicator	conclusion indicator	
	enthymeme		
	conjunctive premise		
Strategies:	simple argument		
	divergent argument		
	convergent argument		
	enthymematic argument		

The premise and conclusion are sufficient to define the simple argument first introduced by Copi and Cohen. The sub-conclusion is an addition by Dr. Odland to distinguish intermediate results in a line of reasoning from the final goal. At this point he followed the Copi and Cohen line and introduced the indicator roles. Believing that explanations are legitimately part of reasoning, he also included the explanation role. To accommodate enthymeme as a distinct form of argument, he included an enthymeme role. There was still some uncertainty about the relation of roles and strategies at this time.

After the simple argument, each of the strategies presented some kind of problem. Divergent argument is really two independent arguments and should not require a strategy template. However, the unstructured form of an argument first used by the text required showing several reasons in support of a conclusion. Divergent strategies with two, and more, premises would be required.

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[31]Details of all models and arguments are in the appendix.

The convergent argument emphasized the cooperation of premises in support of a conclusion. To copy the diagram in the text, Dr. Odland wanted to create a link structure which was not possible in Peitho [Figure 4.15 a)]. Instead he created an extra role -- conjunctive premise -- to emphasize the connection [Figure 4.15 b)].

The enthymematic argument is not general; it only allows the supporting premise to be missing although the text contains examples with a missing conclusion and with both conclusion and one premise missing.

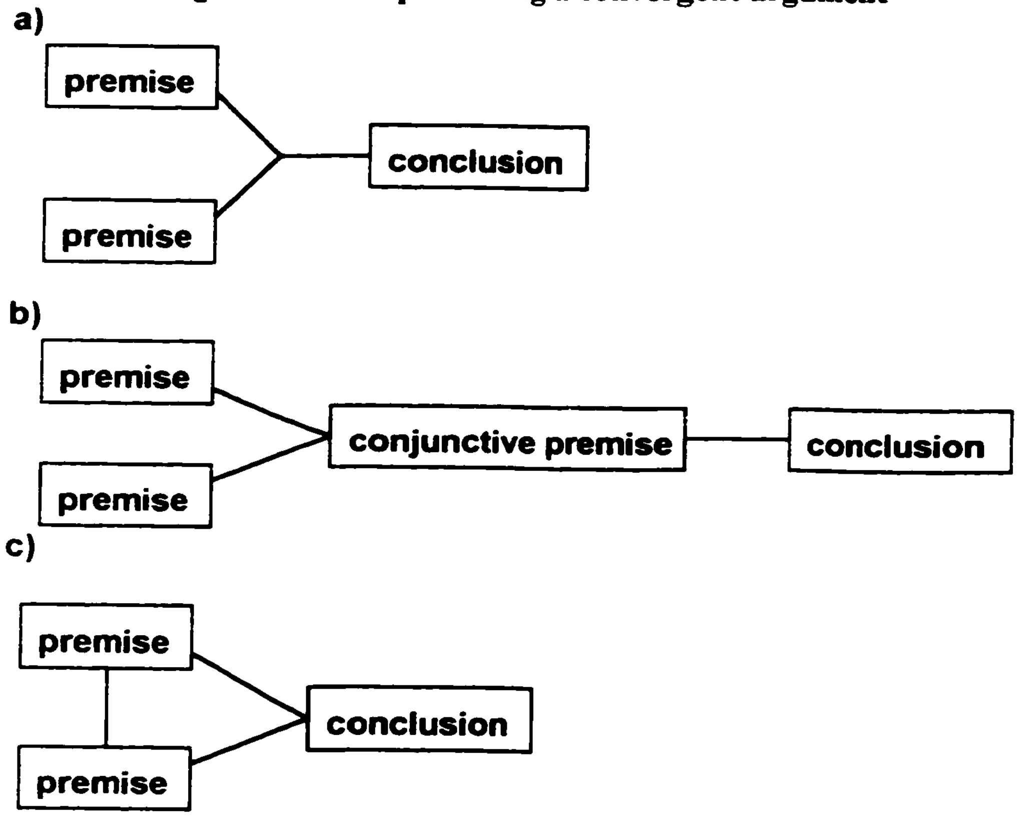
Problems in this session come from two sources. First, Dr. Odland's inexperience led him to miss a more direct way of representing the convergent argument without creating the conjunctive premise [Figure 4.15 c)].

More significantly, problems with the representation of the enthymematic argument and the divergent argument are related. Although the divergent argument could be represented as two, the authors explicitly state that they are following the convention that one conclusion indicates one argument. Hence, Peitho should be able to accommodate the model. This could be done in a clumsy fashion by defining strategies with one, two, three and more premises supporting the conclusion. Alternately, Peitho could be revised to allow for a more flexible definition of strategies so that the simple argument strategy could be defined as n premises in support of a conclusion and the user could specify n.

This approach would weaken one of Peitho's primary analytic features. If the user could vary the number of nodes in a strategy, the absence of facts in an argument would no longer be a certain indicator of unstated propositions.

Now this feature would be sufficient for the representation of enthymemes, so the *enthymeme* role and the *enthymematic argument* strategy would be unnecessary.

Figure 4.15: Representing a convergent argument



- In the second session, January 17, Dr. Odland used the informal reasoning environment to represent a sample argument, Copi and Cohen, p. 53, #20.

> *A disease entity is defined by signs and symptoms generated by objective - that is, organic - determinants. Thus ... illness is organic. Since mental disturbances are not organic, mental illness is not illness.* Dr. Thomas Szasz.

Dr. Odland had some difficulties with the Peitho interface but the representation of the Szasz passage was generally successful. The *convergent argument* strategy was used so the *conjunctive premise* role had to be filled. He wanted to put both propositions into the node but this was not possible so a new statement was added: "Conjunction of 2 and 3" but the detailed description included more structural information than content. Support was included for the some of the statements as well as analytic comments.

Although the argument was not constructed and analyzed exactly as intended in Peitho, the result was insightful, particularly when displayed in the linearized structure. See the note in Appendix C on this session.

- In the session of January 24, Dr. Odland was unable to stay long enough to use Peitho. We briefly discussed his reflections on previous sessions - he would like to have a way to look at all the arguments in a line of reasoning at once. This is possible but clumsy in the current implementation of Peitho.

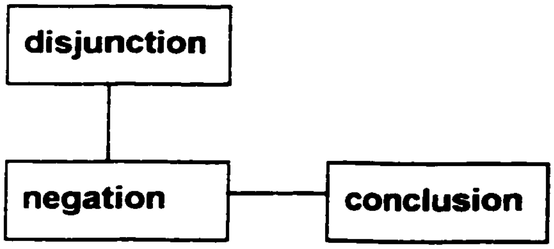
- On January 31, Dr. Odland wanted to redo the strategies he had originally defined for informal reasoning. He had identified that the *conjunctive premise* was an artifact of the translation to Peitho and had no justification in the model of reasoning. His tactic, unlike mine, was to consider compound statements directly and he began to create the inference rules which would later form the basis of a deductive system. With these compound rules in place, he created true strategies which again foreshadowed the deductive model.

The reasoning environment was extended as follows.

roles:	disjunction	conjunction	negation
	hypothetical proposition		
	hypothetical major	hypothetical minor	
	hypothetical conclusion		
	antecedent I	antecedent II	antecedent III
	consequent I	consequent II	consequent III
strategies:	disjunctive syllogism		
	hypothetical syllogism		

The first four roles are compound propositions and implement the standard operators of first order logic: $\vee$, $\wedge$, $\neg$, and $\rightarrow$. With *disjunction* and *negation*, he defined the *disjunctive syllogism* strategy ($(A \vee B) \wedge \neg A \rightarrow B$) quite clearly as in Figure 4.16.

Figure 4.16: Disjunctive syllogism

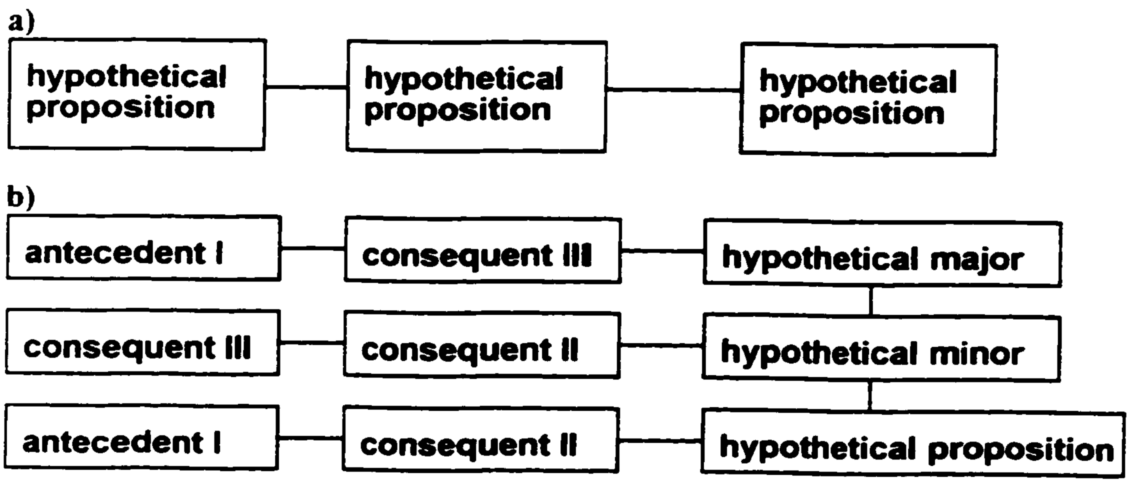


The *hypothetical syllogism* caused problems. Unlike the other two strategies, it establishes a claim which is a non-decomposable compound statement: a hypothetical proposition. The other roles listed were defined in attempts to properly represent it. The fundamental issue for Peitho is that the roles cannot be defined independently of the nodes in the strategy. The strategy should be as in Figure 4.17 a).

In this diagram, the reappearance of consequents as antecedents is not represented as it should be. Dr. Odland attempted to solve the problem by defining a suite of antecedents and consequents and representing the syllogism at a more detailed level as in Figure 4.17 b).

Unfortunately, this representation is grounded in the atomic propositions and is no longer 'hypothetical' although the written description of the strategy is.

Figure 4.17: Hypothetical syllogism



- On February 7, Dr. Odland and I discussed the problem that had arisen with the hypothetical syllogism. He interpreted it as difficulty with the level of detail of representation.

He entered two examples to the revised system. The first was a passage from Bertrand Russell:

Copi and Cohen, p.52, #12

Does the past exist? No. Does the future exist? No. Then, only the present exists. Yes. But within the present there is no lapse of time? Quite so. Then time does not exist? Oh, I wish you wouldn't be so tiresome.

This passage was represented using two convergent argument strategies, including conjunctive premise roles for which two extra statements were added. 'Conjunction A' joined *Does the past exist? No.* and *Does the future exist? No.* while 'Conjunction B' joined *Then, only the present exists.* and *But within the present there is no lapse of time? Quite so.*

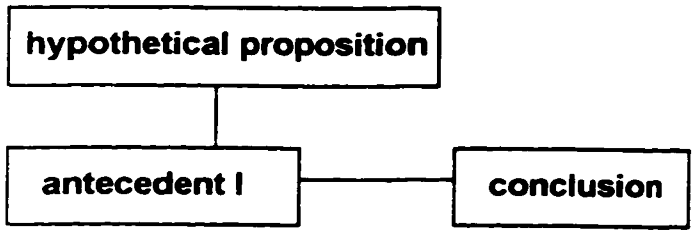
The structure graph displayed the argument clearly and the extraneous statement (*Oh, I wish you wouldn't be so tiresome.*) was identified with warnings because it was unused and because it was a second claim. Appendix C shows the structure with and without warnings.

Pilot: deductive reasoning

That same day (February 7) a second passage was analyzed, from Roger Bacon, Copi and Cohen, p.309, #27:

And certainly if its essence and power are infinite, its goodness must be infinite, since a thing whose essence is finite has finite goodness.

Figure 4.18: Modus Ponens



This passage is taken from the section on deductive reasoning in the text and contains an invalid argument. We considered it a good deductive example to start with and the first analysis was done in the informal reasoning environment.

Its single argument was represented as a *convergent argument* strategy but Dr. Odland described the fallacy -- denying the antecedent -- in the text box. It was evident that the informal *convergent argument* strategy was not the best basis for investigating the fallacy: the explanation involved the hypothetical proposition but this role did not appear in the argument! This representation failed to capture the problem.[32]

From this experience, Dr. Odland returned to builder mode to add a *modus ponens* strategy ($A \supset B,\ A \therefore B$), defined with a *hypothetical proposition* and an *antecedent*.

We discussed the various viewpoints of the basic modus ponens inference rule. See Figure 4.18.

- On February 14, Dr. Odland constructed a final argument in the informal environment before investigating deductive reasoning strategies. Again the example was chosen from the deductive reasoning section, Copi and Cohen, p.399, #18.

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[32]Notice also that Dr. Odland did not explore the analysis features of Peitho to any extent. Here he wrote his critique in the description of the argument rather than in the analytic notes which were intended for this purpose.

Although world population is increasing, agricultural production is declining and manufacturing output remains constant. If agricultural production declines and world population increases then either new food sources will become available or else there will be a radical redistribution of food resources in the world unless human nutritional requirements diminish. No new food sources will become available, yet neither will family planning be encouraged nor will human nutritional requirements diminish. Therefore there will be a radical redistribution of food resources in the world. (W, A, M, N, R, H, P)[33]

The approach was to represent each of the seven premises in the passage as a statement then construct five compound statements representing the individual sentences. (Sentence three was treated as a pair: *No new food* and *neither family planning nor diminished nutrition.*) Along the way, some problems were identified and fixed. For example, Dr. Odland had some 'indicators' in the original premise statements but these were removed. However, the representation of some of the sentences as statements was unsatisfactory -- these constructs should have showed up in the arguments. Furthermore, external support was added for all the individual statements, which conflicted with the denial of some of these in the sentences, e.g., new food sources.

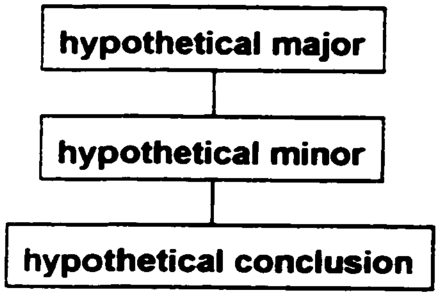
The representation clearly was ineffective and was abandoned. We agreed that this example would be a good one to explore with a deductive reasoning environment.

---

[33]Copi and Cohen provide hints to solving some passages in the form of a set of letter references to the propositions students should be looking for. These are used in the sample answers in the back of the text.

- On February 28, Dr. Odland began by making revisions to the informal reasoning environment. He replaced the multiple antecedents and consequents with one each and rewrote the hypothetical syllogism as in Figure 4.19.

Figure 4.19: Hypothetical syllogism - revised



He then revisited the previous 'food' example and identified and removed the statements which should have been arguments. Because the revised reasoning environment could not be attached to the current example, he redid the example.

The problem remained, however, that the argument is structurally complex and the representation of individual premises and then compound statements was not very enlightening. Adding the alphabetic code reference used in the text did not help substantially. We identified the primary problem as a difficulty with representing compound expressions as claims in the Peitho system. We agreed that I would try to create a deductive reasoning environment based on the inference and replacement rules of Copi and Cohen. Their rules are reproduced in Appendix B. Using this environment, we would try again to represent the same passage.

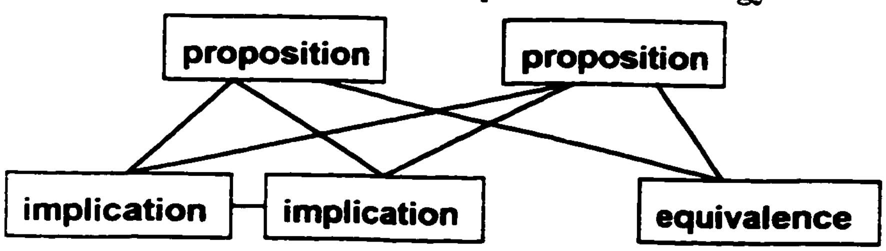
- At the March 6 session, we inspected my deductive reasoning environment and Dr. Odland made a few minor corrections to my sloppy terminology.

Nonetheless, the strategies were not completely satisfactory. As discovered before with the hypothetical syllogism, the representation of the compound expressions as roles was one problem. It showed up here in several strategies in the same form: the role was not independent of the place it fit in the strategy. There was a related problem of sheer number of compound roles required. For example, the *Material Implication* tautology expressed the equivalence of $(p \supset q)$ and $(\sim p \vee q)$ but the roles used were *implication*

($p \supset q$) and *disjunction* ($p \vee q$). To avoid this problem, a separate disjunction role with one negated proposition would have to be defined. The tactic used in these definitions was to write the actual expressions in the text of the strategy while keeping the roles as general as possible.

The inference rules, while suffering from this difficulty, were at least presented as hypothetical arguments. The tautologies were represented as compound structures based on atomic propositions. Each side of the tautology was defined by one or more roles. Material equivalence, $((p \equiv q) \equiv [(p \supset q) \bullet (q \supset p)])$ in Figure 4.20, is an example.

Figure 4.20: Material Equivalence tautology



A second problem with tautologies was the bidirectionality. They were expressed as paired results built from the same atomic premises but, by design, only one could be the **claim** of the strategy, as equivalence is above.

In spite of these drawbacks which put into question any claim that Peitho would support a user constructing a deductive argument, we decided to proceed to see if the environment could represent the argument of the 'food' passage.

This time the propositions were identified by the letters suggested in the passage in the text and Dr. Odland attempted to construct the deductive line of reasoning as he did in class. On my suggestion, he did this in Peitho without writing it on paper first. The effort was successful. The linearized structure produced by Peitho was clear and understandable. With some options included, this was the result. Details are in Appendix C.

code:

W: **World population is increasing.**

A: **Agricultural production is declining.**

M: **Manufacturing output is constant.**

N: **New food sources**

R: **Redistribution of food resources**

H: **Human nutritional requirements diminish**

P: family **Planning is encouraged**

statements

```
1. W ^ (A ^ M)                      R
2. (A ^ W) -> [(N \/ R) \/ H]       R   (nc evidence)
3. ~N ^ (~P ^ ~H)                   R
4. R                                A
5. A ^ W                            A
6. (N \/ R) \/ H                    A
7. ~N                               A
8. R \/ H                           A
9. ~P ^ ~H                          A
10. ~H                              A
```

linearized with structural parts and strategy names

```
Analysis of Argument: d:\1peitho\mar06\dedfood
. 1 Thesis of the argument: R
. . 2 [Argument: Disjunctive syllogism]
. . 2 Claim: R \/ H
. . . 3 [Argument: Disjunctive syllogism]
. . . 3 Claim: (N \/ R) \/ H
. . . . 4 [Argument: Modus Ponens]
. . . . 4 Claim: (A ^ W) -> [(N \/ R) \/ H]
. . . . 4 - - - - - - - - - - - - - - - - - - -
. . . . 4 Claim: A ^ W
. . . 3 - - - - - - - - - - - - - - - - - - -
. . . 3 Claim: ~N
. . . . 4 [Argument: Simplification]
```

```
. . . . 4 Claim: ~N ^ (~P ^ ~H)
. . 2 - - - - - - - - - - - - - - - - - - - -
. . 2 Claim: ~H
. . . 3 [Argument: Simplification]
. . . 3 Claim: ~P ^ ~H
. . . . 4 [Argument: Simplification]
. . . . 4 Claim: ~N ^ (~P ^ ~H)
```

Dr. Odland then completed another example: Copi and Cohen, p.399,#15. This passage was considered representative of the course and had been used as an examination question.

If the Mosaic account of the cosmogony is correct, the sun was not created till the fourth day. And if the sun was not created till the fourth day, it could not have been the cause of the alternation of day and night for the first three days. But either the word "day" is used in Scripture in a different sense form that in which it is commonly accepted now or else the sun must have been the cause of the alternation of day and night for the first three days. Hence it follows that either the Mosaic account of the cosmogony is not strictly correct or else the word "day" is used in Scripture in a different sense from that in which it is commonly accepted now. (M, C, A, D)

In representing the passage, the four statements for M, C, A, and D were included as the first four statements although we knew this would cause warnings in the Peitho linearized graph. Aside from this, the line of reasoning was constructed as in the previous example.

statements

```
1. Mosaic cosmogony is correct.(M)
2. Sun was not created until day 4.(C)
3. 1st 3 days sun didn't cause change (A)
4. 'Day' is used in a different way.(D)
5. If M, then C.                            R
```

If the Mosaic account of the cosmogony is strictly correct, the sun was not created till the fourth day.

6. And if C, then A. R

And if the sun was not created till the fourth day, it could not have been the cause of the alternation of day and night for the first three days.

7. Either D or not A. R

But either the word 'day' is used in Scripture in a different sense from that in which it is commonly accepted now or else the sun must have been the cause of the alternation of day and night for the first three days.

8. Hence either not M or D. A

Hence it follows that either the Mosaic account of the cosmogony is not strictly correct or else the word 'day' is used in Scripture in a different sense from that in which it is commonly accepted now.

9. If M, then A. A

10. If A, then D. A

11. If M, then D. A

linearized with strategy names

```
Analysis of Argument: d:\1peitho\mosesevd
. 1 Sun was not created until day 4. (C)
. 1 Hence either not M or D.
. . 2 [Material Implication]
. . 2 If M, then D.
. . . 3 [Hypothetical syllogism]
. . . 3 If M, then A.
. . . . 4 [Hypothetical syllogism]
. . . . 4 If M, then C.
. . . . 4 - - - - - - - - - - - - - - - - - - -
. . . . 4 And if C, then A.
```

```
. . . 3 - - - - - - - - - - - - - - - - - - - -
. . . 3 If A, then D.
. . . . 4 [Material Implication]
. . . . 4 Either D or not A.
. . . . 4 - - - - - - - - - - - - - - - - - - - - -
. . . . 4 1st 3 days sun didn't cause change (A)
. . . . 4 - - - - - - - - - - - - - - - - - - - - -
. . . . 4 'Day' is used in a different way.  (D)
. . 2 - - - - - - - - - - - - - - - - - - - - -
. . 2 Mosaic cosmogony is correct.  (M)
. . 2 - - - - - - - - - - - - - - - - - - - - -
. . 2 'Day' is used in a different way.  (D)
```

This example included two applications of the Material Implication tautology. Fortunately, the substitution was represented in the right direction in the strategy; that is, the union, $(\sim p \vee q)$, was the claim.

- On March 13, we analyzed the Mosaic passage. It was evident that a pair of strategies was required for a tautology, one for each substitution. The simplification would make the strategy diagrams more understandable also.

To complete the deductive model Dr. Odland incorporated an evidence set. This feature was tested by extending the representation of the Mosaic passage. Details are in the appendix.

4.4.4.5 Interpretation of the connoisseur evaluation

The interpretation is organized around the five questions concerning Peitho's effectiveness. The first four are answered from the evidence gained in the connoisseur evaluation and the direct analysis of the Copi and Cohen text. Several themes have emerged and, for each of these, the experience from the two sources is discussed. As the purpose of this study was primarily summative, the criticism of Peitho is restricted to the model and major design issues.

With this background, Dr. Odland's judgment of Peitho's potential for learning is presented and interpreted.

The section concludes with my lessons from the experience.

Question 1: Representation of models

The informal reasoning model of Copi and Cohen was not expected to present any difficulties in representation whereas the deductive model was expected to be a challenge. The detailed analysis of the text and the connoisseur evaluation confirmed this.

Doing the informal models, Dr. Odland had some problems with role definitions -- for example, premise indicator as a role -- but these were resolved as he gained experience.

In deductive reasoning, the models could be constructed in Peitho, but the system did not capture the aspects necessary to portray the structure-based inference. This weakness was identified in the text analysis and in the connoisseur evaluation and suggested some changes to the design of Peitho. These are discussed further in the context of question 3.

Question 2: Representation of arguments

Peitho represented the arguments in all the passages of the connoisseur evaluation. No problems with representation were uncovered in analyzing the textbook either. In fact, the representation was easier using models from Copi and Cohen than some of the other textbooks investigated earlier. Copi and Cohen are quite rigorous about treating every proposition separately and this fits well with the role and strategy structure of Peitho. Other authors are less committed to analysis at the 'proposition' level of detail. Toulmin, for example, often clusters several proposition statements as *grounds*.

Question 3: Support for design of models

To *support* model design requires more than mere representation. At worst, Peitho could represent the concepts of the model but obscure them for the user. Or, Peitho could express the model in a way to clarify the concepts for a user. A related possibility concerns the support Peitho can provide to the model builder in challenging the model itself.

Here, these possibilities -- obscure, clarify and challenge the model -- are considered for the features in the study.

• Argument structure was an issue in both the text analysis and the connoisseur evaluation. Generic argument structures, multiple roles of propositions as conclusions and premises, lines of reasoning are all rendered concrete in the Peitho system. The only drawback is the inflexible implementation of strategies which forces the generic argument the authors begin with -- one or more premises supporting a conclusion -- to be provided as a set of strategies with one, two, three,... premises.

Although independent premises are intended to be separate arguments in Peitho, the system can handle the Copi and Cohen 'one conclusion means one argument' model and distinguish the independent premises from dependent ones, although, in the connoisseur evaluation, the strategy of cooperative premises was not represented well.[34]

By extension, two claims mean two arguments. In Peitho this means two argument forms whereas the text diagram looks like one argument with two conclusions.

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[34]i.e., Dr. Odland did not represent the strategy of dependent argument as well as he might have in Peitho.

The distinction between arguments and explanations was representable in a variety of ways in Peitho. Essentially, explanations were shown to be a valid aspect of reasoning, as roles or as evidence types, and the Copi and Cohen approach of excluding explanation was called into question.

In representing the model of deductive reasoning, Peitho showed some weaknesses. Compound propositions presented a problem - as roles they were not independent of the position they filled in a strategy, for example the hypothetical syllogism. This led to defining the role very generally and losing the significance of the component propositions or defining many versions of the same compound proposition.

Tautologies were not successful in Peitho - it was awkward to represent them independent of their atomic proposition components and it was necessary to create two strategies to capture the bidirectionality of each one. Correcting this is a design problem for Peitho.

• Hypothetical propositions were introduced in the chapter on informal reasoning. Peitho clearly makes the authors' main point that hypothetical propositions are not arguments: they are defined as roles with compound propositions. When hypothetical propositions play a warranting role in a strategy, this model is clear. However, in the deductive reasoning model, the problems of compound propositions arose for hypothetical propositions.

• The cyclical activity of using Peitho also supported the design of the critical thinking model. Not surprisingly, this theme was only evident in the connoisseur evaluation.

Question 4: Support for development of arguments

• Premise and conclusion indicators are supposed to help identify the roles of the propositions in an argument. In Peitho, the indicators are graphic: the links and positions of the nodes in a strategy. The text inadvertently bestows upon the indicators a status equivalent to a proposition. Dr. Odland initially represented the indicators as roles but corrected this so the Peitho model does not contain this category error.

Nonetheless, the design of Peitho needs to be revised to include a variety of links so the strategies can more clearly describe the structure that indicators provide in text.

• Enthymemes are represented in Copi and Cohen with distinct diagrams. This is not necessary in Peitho - indeed, any strategy is potentially enthymematic as the system provides warnings when roles are not filled with statement facts.

However, this support is based on strategies having particular roles to fill. The Copi and Cohen approach of introducing a generic premise/conclusion model of argument first makes the recognition of implied statements more difficult - there is not much basis for a beginner to choose an argument with an unfilled proposition over another argument with fewer propositions to fill. If this approach were to be followed, Dr. Odland's enthymematic argument strategy would provide the concrete structure to alert the user to missing statements.

• The distinction of structure from content is an on-going theme of introductory level critical thinking. This issue has already been partly addressed in the discussion of indicators and hypothetical propositions where Peitho helps to clarify the distinction by making it concrete.

In the text, the authors have, I claim, confounded a structural distinction between deductive and inductive reasoning with a distinction of content. In this claim I am strongly influenced by formal reasoning, in particular mathematics, where induction has a specific meaning of generalization of a proposition about individual elements of a set to a proposition about all members of the set. In informal reasoning, the concession is that the generalization is not eternally true, not 'above time.'

Now, Copi and Cohen include reasoning by analogy as inductive reasoning; in fact, analogy is the first topic in the induction section. If the stricter definition of induction is used, then analogy is not induction; it is rather a chain of argument, induction followed by deduction, as described above. This model is cleaner conceptually, but it is also practical because the resulting structure -- as represented in Peitho for example -- focuses the user's attention on the factors of structure and of content which need to be tested to determine the strength of the chain of argument.

The potential of Peitho to clarify the distinction between structure and content came up in the two passages which contained invalid arguments. In the Szasz passage about mental illness, the structure is valid so the focus of the challenge is on the content of the propositions. (See the analysis in the Appendix C.) Similarly, in Bacon's argument about power and goodness, the structure of the argument strategy forces a mismatch of proposition to role, if Modus Tollens is used, identifying that the problem is structural.

• The linearized graphs of Peitho turned out to be a powerful support to understanding and analyzing lines of reasoning in spite of the weak format of implementation. The structure of the graph did transfer to a big picture of the chain of argument, especially when the graph was drawn and redrawn with information features turned on and off. This feature was only identified in the pilot study of course.

• In the pilot, cycling among the modes of operation of Peitho was also helpful to understanding and building the arguments, especially in the deductive passages when statements were added incrementally to the original set.

It did become clear that a capacity to cycle between the builder and user roles would also be useful. Many of the insights about building the model came from trying to apply it to a passage. Sometimes I was able to kludge together a revised model with a current passage but often Dr. Odland was reduced to re-entering the data for the passage into the new model. In general, a less strict demarcation between user and builder needs to explored.

Question 5: Support for teaching and learning

Sufficient agreement between the text analysis and the pilot study has been found to validate the potential usefulness of Peitho for user and builder. It also validates the experience of Dr. Odland and provides a basis for his evaluation of Peitho as an environment for learning critical thinking.

Dr. Odland wrote his final impressions shortly after the last session of the study. The complete text of his report is included in Appendix A. He prefaced his evaluation with two remarks. One concerned his lack of experience with computers which did cause him to struggle with the interface prototype. He was not comfortable with the use of the mouse and the conventions of menu symbols for example. Undoubtedly, this interfered with his mastering of the basic features of Peitho. He also noted that he would have grasped the operation of Peitho more quickly if I had provided some hard copy instructions.

His second remark concerned his experience teaching introductory logic. He had never developed a course 'on his own terms.' He stated that the experience with Peitho left him more prepared to do so.

Nonetheless, he did become quite expert and his experience was significant.

Concerning the building of models (questions 1 and 3), Dr. Odland's remarks confirmed the preceding analysis. He saw the informal reasoning models well represented in the Toulmin-like style which he saw in Peitho. In deduction the tautologies were not adequately handled but inference rules were. He observed that the effectiveness of the system for a user hinges on the templates created by the builder. He felt the system allowed sufficient scope for an instructor to build templates for use by their students. Interestingly, he thought better support for the builder in using colour was important.

For the user constructing an argument (questions 2 and 4), he wanted a visual representation of a complete line of reasoning[35]. He also requested a way to flag the "indicators" of premises and conclusions.

In spite of these omissions, he saw value in Peitho for learning. He had prefaced his evaluation by saying the experience had been valuable for him as an instructor and course developer but he also described potential for students using the system.

Several of his claims were discussed above. Essentially, his point was that the concrete and active representation of the concepts supports students learning them:

- assertions alone are not arguments;
- explanation is different from argument;
- validity is distinct from truth.

More speculatively, he suggested Peitho would also support the learning of other topics in the logic curriculum:

- fallacies of relevance and ambiguity,

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[35]The linearized graph is available for analysis, and multiple argument forms can be open at the same time, but these are inadequate. I see this, like the suggestion about colours, as an implementation issue.

- definition,
- different uses of language,
- rhetorical presentation.

Finally, he also was of the opinion that skills of construction, as well as analysis, would improve through the use of Peitho, though we had not experimented with constructing an argument.

Reflections

After this connoisseur evaluation, and in spite of the problems of using a crude interface, I am encouraged that the Peitho model can be effective. Dr. Odland found the experience useful for himself and felt it could be for his students. Mostly, the study confirmed what was expected; nonetheless, it was a thrill to see the insights emerge for Dr. Odland as his skill developed.

The study revealed weaknesses in Peitho as well. None were fatal flaws in the model but several problems suggested that a redesign of the software is the next step:

(i) redefinition of strategy structures, with more representational power in the links and support for compound propositions,

and

(ii) redefinition of the distinction between user and builder activities.

The potential of the system was confirmed and the changes are well worth continuing the development.

5. Discussion of Results

In this chapter the work of the project is critically examined. First the methodology is reviewed then the project is evaluated according to the original goals.

5.1 Effectiveness of Cohen Development Strategy

The research model proposed by Cohen was inspired by his observation of much computer science research as either narrow and ungeneralizable, or abstract and untestable. Cohen puts constraints on the researcher to think in terms of theoretical models that are tested as programs and generalized from that testing. He has been careful to assure that the undeniably creative activity of programming is not stifled by adherence to his requirements.

In fact, my subjective impression is that Cohen's framework complements programming as research because it distinguishes theory revising from redesign (and from debugging). While it has long been accepted that design is distinct from coding, I feel I gained an awareness of a similar distinction between design and theory and benefited from knowing which kind of revision I was contemplating.

One major advantage was in the experimentation stage. The testing of software is often a neglected stage of development, but having a clear concept of the behaviour intended in the theory allowed me to focus on testing that the design implemented it.

The research model has also provided a structure for recording the project. In chapter three, the environment was described as a parameterized space, and the goals of the project were stated as predictions. Chapter four detailed the final versions of the model and design, together with an epitome of the experimentation. Even the connoisseur evaluation benefited from the research model. The clear distinction of theory from implementation drove the planning of the connoisseur evaluation and informed the observation and analysis.

In the following sections of this chapter, the explanation phase is added. It is an application of connoisseurship and criticism.

5.2 Explanation

In contrast to the formative explanations undertaken in the development cycle described in chapter three, the purpose of this explanation is both formative and summative. The primary goals are considered first and the secondary concerns with features relevant to the hyperintelligence literature are discussed later.

If the conclusions drawn from the explanation are going to be generalized, they must take into account the variations in the environment: four kinds of critical thinking at five different levels of activity in a variety of disciplines. To describe, interpret and evaluate the behaviour of Peitho's model and design exhaustively in each possible combination is prohibitive. It is also unnecessary because the effect of changing the parameters of the environment is completely describable in the model. Hence the explanation is based on describing the parameters and then interpreting the extended example and the connoisseur evaluation of chapter four.

5.2.1 Description: Effect of Changing the Environmental Parameters

Four ways of applying critical thinking were to be attempted within the model. (See 3.1.1 Environmental factors.) Each of these can be described in terms of the model.

i) *to construct a chain of reasoning in support of a specific claim*

When the major claim is a fixed feature, as for example when one is building a formal proof of an intuitive insight, the chain of reasoning must be constructed back to statements which are supported in the domain.

The activity is supported by the model. An empty generic argument is created to support the major claim. The strategy templates guide the consideration of a format for the proof and, when a strategy is selected, the roles in the argument guide the search for statements to apply it. Alternative proofs and multiple steps of chains can be explored concurrently.

ii) to generate a claim implied by a set of information

This is the creative use of critical thinking. The fixed feature is a set of statements, presumably all accepted in the domain, and the goal is to reason forward to a major claim. Interpreting a set of data according to an accepted theory is the epitome example.

This is also the activity described in the exploration of the Sappho poem. It is supported by the system which guides the grouping of statements into strategies which can be plausible arguments for a claim. The claim is added to the statement set.

A variation on this activity would apply to exploring a theme, as a student might do in the prewriting phase of an essay. The difference is that the set of factual statements from the domain is not fixed. Exploring an argument might lead to a strategy with an interesting claim but with a 'hole' at one of its roles. This would guide the focus backwards to seeking a fact to fit the role.

iii) to critique an existing chain of reasoning

This is the user activity explored in the connoisseur evaluation. Instead of trying to generate the major claim, the purpose of the activity is to build an internally consistent chain of reasoning developing it. As Wickelgren (1984) points out, the resulting structure may be the same but the activity is different because the explicit claim is a given. The reasoning activity can proceed both forward and backward.

If understanding the document is preliminary to critiquing, then the next stage is to examine the resulting chain for enthymemes (automated) and for the strength of the arguments (by advice).

iv) to engage in dialogue for reconciliation (synthesis, selection, arbitration, accommodation, assimilation...) of conflicting claims.

When the critiquing of a chain of reasoning is done in the context of a dialogue, more is required than just an evaluation. To advance the discussion, the response must be related to the position evaluated, providing arguments to extend or refute it. These activities (e.g., Missimer, 1986) can be represented as argument strategies so the construction of a response, which essentially subsumes the original chain of reasoning, is possible in the model.

Of course, the model does not include a representation of discourse. However it is clear that at least two extensions are suggested. One builds upon the notion of critiquing and the capacity in the software to evaluate and keep notes on an argument structure. The other takes the discourse as an expanding argument structure, in which a new speech act extends - or subsumes - an existing chain of reasoning representing the discourse to date. The software includes no capacity to manage participation in discourse.

The environment also spans a range of users from learners to experts and instructors. This parameter has been operationalized in the five levels of activity of subsection 3.2.3. The Sappho example and the four critical thinking activities just discussed have been described at the 'learner expressive' level, the second of the five levels. This level is associated with having all user facilities of the program available but no access to the design-in-use builder facilities. The 'learner instructional' level involves constraints on the model used in the extended example.

The 'expert expressive' level is identical in program activity. The only difference is that the expert user is working without an instructor as external evaluator.

At the 'expert creative' and 'instructor creative' levels, the builder facilities are also accessible. The expert's goal is still to pursue one of the critical thinking activities with the added power to create new strategies. The instructor uses the same program environment but the goal is to export templates which will enable activities in the learner levels. Table 4.8 summarizes the range of alternatives.

When the instructor defines a template with no alternatives, the effect is to constrain the learner's choices and control. This produces an instructional environment where a specific response is expected. For example, if a one step argument is presented to the learner to critique, and there is only one argument strategy available, a single interpretation could be acceptable as correct.

The third environmental parameter is domain of discourse.

> "We understand the fundamental force of medical arguments only to the extent that we understand the enterprise of medicine itself. Likewise for business, politics, or any other field. In all these fields of human activity, reasoning and argumentation find a place as central elements within a larger human enterprise. And to mark this feature - the fact that all these activities place reliance on the presentation and critical assessment of 'reasons' and 'arguments' - we refer to them all as *rational enterprises*." (Toulmin, Rieke & Janik, 1979, p.28)

The environment in which Peitho is used is that of the rational enterprises. The model incorporates the invariant features and permits the representation of the distinguishing structural ones through the builder mode and templates. The 'fundamental force of arguments' is a semantic issue and is available in the program to the extent that it is conveyed through the content of statements. From the initial design decisions, there has been no claim of analytic power within domains of discourse but the availability of templates permits guidance at whatever level of detail is appropriate. The experience with formal deductive logic in the connoisseur evaluation tested the bounds of Peitho in a domain where analytic power based on structure is important.

5.2.2 Interpretation of the Model and Design

The goal of the structural model was to represent chains of reasoning based on a unit argument and an extension for multi-step reasoning. Acknowledging Smith's concerns about students being controlled by the reasoning model in software (LeBlanc, 1992), and on the insufficiency of the Toulmin basic pattern of analysis, the unit argument is defined generically. With this change, and the use of a general systems model defined as a graph to represent the chain of reasoning, the theoretical model successfully represents any examples tested.

In a sense, this model is at a lower level than the one proposed but capacity to represent the properties of the reasoning structures is restored through the extension of the model with the templates[36]. Toulmin's basic elements have been replaced by the generic nodes but the concept of role reintroduces the element types; similarly the structure of argument is lost in the generic representation where an argument is a general graph but reappears in the strategy types.

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[36]The Toulmin pattern of analysis can be represented in this model so it subsumes and is at least as powerful as the original proposal.

The concept of supports and evidence types is a new feature, not foreseen in the original proposal. It explicitly represents the connection of the chain of reasoning to its domain of discourse and provides closure to the systems model.

The process model of critical thinking has also been completely implemented with the three projected modes of activity. The separation of the representation into generic structure and templates for properties is complemented by the separation of the activities into two levels, one for designing the templates and one for applying them to guide critical thinking.

While the program demonstrates the adequacy of the model, there are design issues which also need to be examined. None of these threatens the model though some might lead to revisions or extension.

The major design issue is the 'chunking' of the model in the programming environment where more precise definition of boundaries is required. In the representation of reasoning, what is properly part of the argument structure (and hence under control of the learner/user) and what is best included in the strategy structure for the builder to define? An example which shows up in the Sappho poem analysis is the rigidity of the strategy graph structure. The "Analysis by Example" strategy has three nodes with role of "fact" and is used twice in the example. Once, the user only has two facts and gets a spurious warning of a missing fact; once the user has four facts and one is left unconnected, producing another warning. The same dilemma arises in the connoisseur evaluation, first with the general argument strategy which has one conclusion and an indeterminate number of premises.

A central design issue concerns how much power the learner should have, if any, to restructure the strategy template imported. In the examples, should the learner be able to replicate the fact nodes or is that a builder activity with implications for the integrity of the strategy?

Similarly, the chunking of the process model is a design question. Where for example should the boundary between structuring and analyzing modes be drawn? Automated analysis of the structure of a chain of reasoning is now an explicit analysis action but it could be implemented as a constraint on the structuring mode which monitors the graph of the chain of reasoning as it develops.

Behind these model-related design issues lies the question of the programming environment. Visual Basic has been adequate for prototyping and demonstrating the potential of the model. It has been less effective, because of its limited and inconsistent data structures[37], in enabling the exploration of design questions.

A second major design question concerns the properties of a strategy which the builder needs to capture the features of the model of argument. Replication of particular nodes has already been described. In the representation of deductive reasoning in the connoisseur evaluation, the need for properties on the links of the strategy graph became clear. In the exploration of tautologies, the issue of multiple points of view on a role or a strategy also surfaced.

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[37]The major problems:

i) minimal dynamic memory allocation, and

ii) an incomplete object-oriented model.

5.2.3 Evaluation of the Model and Design

The model has successfully met the goals set for the four critical thinking activities. Creating a chain of reasoning in support of a claim is demonstrable, as is the critiquing of an existing chain or reasoning. The potential for plausible thinking has been demonstrated, and in fact, has also been shown within the framework of the model itself, even without the link to other analytic software as was originally proposed.

The potential for discourse and dialogue has been explored to the extent proposed. The advancement of a dialogue has been defined in terms of the model, at least for a single step: the complementary position is represented as a chain of reasoning then subsumed into a response. Nothing can be said about the ramifications of extending the model to a multi-user environment - and there are many, as others have documented.

In the matter of interdisciplinary problem solving, a start to cooperation can at least be defined in terms of the model. The critical thinking environment would include the template sets from both -- or all -- disciplines. The problem would be expressed as a set of statements and the set would be extended with the general statements expressing the values and assumptions of each party as these were required in the development of arguments. At least the generic system would be common and the points of disagreement would be clarified. The set of templates could be augmented with strategies derived from the systems which support cooperative work decision making. Perhaps the major contribution of these systems is the real-time parallel nature of the activity which avoids many of the issues of turn-taking discourse.

One aspect of the model which needs further study is exemplified in the question of domain of discourse. Critiquing a poem is different from critiquing a legal argument. The system can accommodate either but there is room for an extension to the model which organizes the representation of those differences. The aesthetic evaluation of the poem is more a matter of constructing an internally consistent interpretation and, as the Sappho example shows, the 'claims' in a poem are often not explicit. A legal argument is more dependent on the strength of support for its facts and the complete chain of reasoning is very explicitly stated. These distinctions should result in different program support. Of course an instructor could include the support in the strategy templates but is another template for domain of discourse a theoretical requirement?

Similarly, the structure of multi-step chains of reasoning needs more theoretical consideration. Are templates of 'classic' chains of reasoning - including fallacies - required? My 'analysis by example' leads me to the conclusion that a complete template-based theory needs to be considered. It seems a natural complement to the simple and accommodating systems model and seems to have potential both as a tool for the instructional designer and as a testbed for conjecture about reasoning and critical thinking in general. This latter notion is pursued in subsection 5.2.4.

As a computer scientist would have predicted, the designing of the software was a powerful source of insight concerning the critical thinking model.

One set of strictly design issues which emerged concerns magnitude and complexity. Is the model useful for a paragraph, a page, an essay, a book? With 'many' statements, hundreds say, can the chain of reasoning still be manipulated as a single structure? There is no exponential order processing waiting to erupt in a combinatorial explosion but the complexity issue is important to the user interface design stage. The first step is to rebuild the system in a different programming environment. Delphi (Obect-Oriented Pascal) and Java are possibilities.

A second set of design issues concerns the potential of the program as a design environment. How well does the 'constraints and properties' approach of professional design fit critical thinking? Peitho demonstrates that some automated analysis based on the graph structure of the chain of reasoning and the properties of the argument strategies is possible. When a cycle is found in a chain of reasoning, Peitho can identify circular reasoning; when the instructor specifies that a role in an strategy needs external support, Peitho can verify that the support link exists. The data structures of the strategies and the chain of reasoning need to be reconsidered to see how much automated analysis can be provided to emulate the professional design environment. The addition of semantics to the links within strategies holds potential for more analysis based on internal structure beyond the current recognition of unfilled roles and missing support.

The text-based advice system that now guides the content evaluation also needs to be reconsidered together with the automated analysis.

5.2.4 Insights about Differences among Models of Reasoning

The Peitho system has been tested and revised by experimentation with various models of critical thinking. The resulting model, while generic, is broad: in scope it is a union of all the critical thinking theories investigated.

Now the system becomes not only a way to represent a theory but also a way to judge how complete the theory is based on how well it spans the territory of critical thinking. From experience with this project, some criteria for judging critical thinking theories seem obvious:

- Is there a vocabulary of elements for describing a reasoning structure?
- What is the 'grain-size' of the representation? Is it fine enough to represent and analyze the reasoning involved? Is the model comprehensive enough to capture chains of reasoning?
- Is there a vocabulary for describing the process and heuristics of reasoning?
- What activities of critical thinking are addressed? Is analysis and critiquing included? Is domain of discourse discussed?

In fairness, most authors would not claim their models cover the range of critical thinking defined here. And there is no suggestion that this categorization evaluates the theories. It is however, a way of comparing models for coverage and provides a little insight on how activities like prewriting and problem solving, which are identified with critical thinking skills, relate to each other.

Aside from completeness and coverage, Peitho reveals any ambiguity in a model of critical thinking when it is concretely represented in templates. This is particularly important in models which are used for instruction. The Copi and Cohen model showed problems in the order of presentation, for example, when enthymemes were introduced in an environment of generic arguments before learners have any concept of the structures in which they are supposed to find missing pieces.

That text also exhibits more important weaknesses, as discussed in the treatment of structure versus content in defining deductive and inductive reasoning. The confounded and ambiguous description leads to problems. For example, as discussed above, the chapter on analogy does not provide much guidance for analyzing analogical reasoning because the model does not provide the structure to focus attention on the points to investigate. My experience with all the texts, and especially the extended investigation of Copi and Cohen with Dr. Odland, leads me to believe that there really is a better way to teach critical thinking based on a simple but rigorous model.

5.3 Hyperintelligence Innovations

5.3.1 Annotated Summaries

The linearized summary which is generated in Peitho is a possible contribution to the problem of introducing new members to a cooperative work environment. In hypertext format, a work in progress may be flexible and insightful, but it is disorienting to newcomers who try to learn it by navigating the hyperstructure.

The linearized summary was originally proposed as an output file to be generated by Peitho for input to a word processor as a document outline. During development, it turned out to be a useful format to overview various aspects of the structuring and critiquing processes. In a cooperative work environment, a similar linearized structure could provide summarized information in an organized and readable format. By turning on various options, specific features of the project could be traced.

The linearized structure is generated as a spanning tree of the chain of reasoning graph. The algorithm works on any graph so could be implemented in any hyperstructure.

5.3.2 Changing Types of Elements

Conklin & Begeman (1988) observed in experience with the first version of gIBIS that recording information directly into roles in the decision structure was too restricting, especially when users were dealing with a new problem where the ideas were vague at first. Based on this caution, the first version of the system in this project was implemented to allow the user to change the type of an element. An undefined type was also included.

As the system evolved, the statement was conceptually separated from the elements in the argument. This made early enumeration of the concepts freer in the information gathering mode, permitted regrouping of statements into argument structures and, once grouped for an argument, permitted exploring of different strategies and roles. The separation of statements from roles also allows any statement to be used in multiple roles while maintaining consistency of content.

While this separation is commonplace in studies of critical thinking, it seems to have potential for work group support software also.

5.3.3 Explicit Representation of Modes / Stages of Operation

The modes-of-operation concept is also undeveloped in work group support software but may have potential. Researchers and users have noted that the decision making structures focus attention on the issues. Modes of operation have a similar potential for structuring the processes by focusing on the specific activity. The separation of information gathering from structuring which is described in the previous subsection illustrates the potential.

5.3.4 Treatment of Generic vs. Domain-Specific Features

The original prediction was based on the observation that tailoring a system to a specific application is a dilemma. If the system is extendible to represent domain specific elements in the decision structure, then the analytic power of the system is compromised; without extendibility, the capacity for representation of features in a specific case is limited.

The proposal was that gateways to other software would allow external domain-specific processing without affecting the operation of the decision-support environment. In the actual research, the gateway potential was verified but not explored to any great extent because the generic model which evolved made the gateways less important. The template approach allows critical thinking environments to be built with complete analytic power, avoiding the dilemma of the decision support environment. The same approach may apply there.

Overall, the model of generic structure with templates seems to have considerable potential for cooperative work software. A general product could be tailored to a particular business environment through template design.

6. Conclusion

There remains only the last step of applying Cohen's model of research: generalizing the results for the environment within which it was conceived and conducted. Before doing this, I want to reflect on the methodology itself.

6.1 Methodology

This dissertation describes a research project which is somewhat unusual in its format. The theoretical model is not supported by an extensive empirical study of its effectiveness. Rather, the theory is justified by a demonstration of its sufficiency as a basis for a piece of software.

As Cohen has described, this approach leads to some questionable practices in computer science unless the research is carefully designed. Cohen created his MAD research model for exactly this purpose and I have adopted it here. I believe this kind of software-based research has a place in educational technology but it is rightly viewed with skepticism. By adhering to this rigourous model, I have prepared to address the concerns and demonstrate that significant theoretical contributions can be made by this approach.

The problem in applying the methodology is that 'proof by software' is harder to justify, the further we stray from the formal, mathematical domains. Establishing how a complex piece of software behaves is not that far removed from quasi-experimental research in the real world. The key has been to ground the evaluation firmly in educational technology and Eisner's work, all stemming from his important insights about aesthetics and learning, is ideal for this. The environment in which the software would be used has been operationalized from his notions of instructional and expressive activities (later extended to include the 'builder' activities). And the 'explanation' of implemented programs has been based on his model of the connoisseur's informed *observation*, *interpretation* and *evaluation*.

With this design, I feel justified in making the general claims that follow. The limited experiment carried out with Dr. Odland has confirmed the insights obtained through the software-based research and should add credibility to the methodology.

6.2 The Final Stage - Generalization

The primary and secondary goals of the project have been met. The feasibility of a model suitable for a software tool to support critical thinking has been established and some of the features of the design show potential as solutions for problems identified in hyperintelligence software.

6.2.1 Theoretical Model

The primary goal of the research has been a model for a system to support critical thinking. The model, as projected, defines both structure and process, but has evolved from the initial conceptions. The structure is generic and simple, accommodating the original Toulmin-based model and others which are incompatible with Toulmin. It incorporates three pairs of complementary structural elements. The process, originally proposed to include information gathering, structural organization and analysis, has been extended with the meta-activity of building strategies of argumentation.

With these modifications, the focus of activity moved to a more abstract level than originally foreseen: instead of providing a model of critical thinking for users to apply, the theory defines an environment for both the construction and application of models of critical thinking.

The model meets the original goals: it is sufficient for doing and for learning critical thinking and it demonstrates potential for interdisciplinary discourse. (It also meets the secondary goal of making small contributions to four particular problems described in the hyperintelligence literature.) Moreover, the increased abstraction of the final model suggests that some broader claims can be made. My original observation -- that defining yet another model of critical thinking would not contribute much to the literature -- remains true; however, by working at a 'lower' level, I have created a meta-model which has considerable potential for characterizing, analyzing and comparing models of critical thinking devised by others. This meta-model also strengthens the claim about potential for interdisciplinary discourse because it shows that strategies from different domains can at least be represented concurrently in a common environment.

The direction of future development is clear. The structural model needs to be reconsidered with an eye to including formally the automated analysis and heuristic advice features. This implies considering the structure of the chains of reasoning to create a theoretical model of the graph structure to drive the automated analysis and advising. This, in turn, leads to an extension of the template model to include standard chains of reasoning.

A parallel development of the process model might also be considered. The basic modes, including 'building,' have been established but there is no mechanism for representing the process heuristics which describe the various activities i a particular domain of discourse in terms of those modes. One should be able to formally describe the strategies of critiquing or generating a chain of reasoning.

The potential for interdisciplinary problem solving has been demonstrated to a limited extent. The next step is to extend the model to a multi-user setting. The investigations suggest two avenues. The first, based on the rhetorical foundations of discourse, would proceed by melding the model with developing theories of computational dialectics (Loui, 1995); the second would treat the chain of reasoning artifact as a shared workspace, according to Thompson's concept (1972), for cooperative investigation in which divergent views would be represented based on the generic common ground.

6.2.2 Software

The use of software in education is so much accepted now that the fundamental advantages are sometimes overlooked. It should be remembered that Peitho is, first, an environment that promotes active, concrete, individualized learning with considerable feedback and guidance for reflection, all with the learner in full control. For the instructor, it provides freedom and support for curriculum design and can even be used for demonstration.

The first proposed use of the system was for learning critical thinking. The professional design model employed in the software development has shown that critical thinking *can* be supported by a design-type environment in spite of the less quantitative nature of the domain compared to drafting or engineering. In fact the graph-based representation of reasoning allows a considerable amount of analysis to take place in support of the critical thinker.

It has also been established that the system can function as a learning environment based on the observation that a design environment is suitable for instructional and expressive activity. The design-in-use capacity based on templates allows an instructor to create sequences of microworlds leading the learner from instructional activities in which the skills are mastered through to expressive and creative activities at the expert level. (The design-in-use concept was, I believe, the inspiration for the extended abstract model of critical thinking which evolved from this research.)

Peitho is again in a state where a complete redesign is required to accommodate further development identified in the previous section. As well as the theoretical extensions, some practical concerns need to be addressed. Scaling up the prototype system to investigate large statement sets and extended chains of reasoning must begin and a proper interface must be designed. There are many commercial systems which can guide this stage of development.

6.3 Epilogue

As a research project, this one has had the feature, both confusing and enlightening, of exemplifying its own content, **chains of reasoning** in support of **major claims** about reasoning. How helpful it would have been to have a software tool, a future Peitho, to support the task. How many more insights might there have been?

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Appendix A

My evaluation of Peitho must be placed in proper perspective: other than word processing and e-mail, my familiarity with software programs is very limited; although engaged in teaching a course in introductory logic at present, I have not developed a logic course on my own terms. Working with Peitho, however, I feel more ready to do so.

If one accepts Toulmin's model of argument (and there is no strong reason not to), then Peitho permits its effective representation. Application of Peitho in courses requiring critical writing would be rewarding for students and would help them realize that assertions on their own do not stand for arguments: a common misconception. Much rests on the templates called into play by the instructor. I would have preferred to have a hard copy of Peitho's organization in front of me from the beginning; the interconnections between the various "levels" would have been clearer.

Peitho's representation of particular arguments seems to me quite satisfactory. Toulmin's model emphasizes inductive arguments but it was possible to structure deductive arguments with Peitho as well. Tautologies may not be particularly well supported, but basic rules of inference can be represented quite nicely. Greater flexibility with color would help the presentation of some of these. It would also be advisable to provide visual representation of extended chains of reasoning. If words which function as indicators of premisses and conclusions could be somehow "flagged," this would be very helpful for the student's analysis of argument.

In an informal logic course certain topics must be considered: the distinction between explanation and argument; validity and soundness; definition; fallacies of relevance and ambiguity; the different uses of language; rhetorical presentation (identifying one's audience, etc.). Peitho could be employed along any of these lines with profit. Students might find it easier to bring together in their writing what they have learned if they can continually call up on the screen whatever is unclear. Both analysis and construction skills would likely improve.

Having spent a number of sessions with Peitho with no clear overview of the process, now that I have a better idea of the parameters, I feel that most instructors could find a use for the program since there is plenty of scope for their own input as "builder." I am persuaded that Peitho has value as an educational aid.

Lance Odland, April 01, 1996

Appendix B Copi and Cohen Rules of inference and replacement

	Rules of Inference		
1	Modus Ponens	$p \supset q$ p $\therefore q$	M.P.
2	Modus Tollens	$p \supset q$ $\sim q$ $\therefore \sim p$	M.T.
3	Hypothetical Syllogism	$p \supset q$ $q \supset r$ $\therefore p \supset r$	H.S.
4	Disjunctive Syllogism	$p \vee q$ $\sim p$ $\therefore q$	D.S.
5	Constructive Dilemma	$(p \supset q) \bullet (r \supset s)$ $p \vee q$ $\therefore q \vee s$	C.D.
6	Absorption	$p \supset q$ $\therefore p \supset (p \bullet q)$	Abs.
7	Simplification	$p \bullet q$ $\therefore p$	Simp.
8	Conjunction	p q $\therefore p \bullet q$	Conj.
9	Addition	p $\therefore p \vee q$	Add.
	Replacement: Any of the following logically equivalent expressions can replace each other wherever they occur:		
10	De Morgan's Theorems	$\sim(p \bullet q) \equiv (\sim p \vee \sim q)$ $\sim(p \vee q) \equiv (\sim p \bullet \sim q)$	De M.
11	Commutation	$(p \vee q) \equiv (q \vee p)$ $(p \bullet q) \equiv (q \bullet p)$	Com.
12	Association	$[(p \vee q) \vee r] \equiv [p \vee (q \vee r)]$ $[(p \bullet q) \bullet r] \equiv [p \bullet (q \bullet r)]$	Assoc.
13	Distribution	$[p \bullet (q \vee r)] \equiv [(p \bullet q) \vee (p \bullet r)]$ $[p \vee (q \bullet r)] \equiv [(p \vee q) \bullet (p \vee r)]$	Dist.
14	Double Negation	$p \equiv \sim\sim p$	D.N.
15	Transposition	$(p \supset q) \equiv (\sim q \supset \sim p)$	Trans.
16	Material Implication	$(p \supset q) \equiv (\sim p \vee q)$	Impl.
17	Material Equivalence	$(p \equiv q) \equiv [(p \supset q) \bullet (q \supset p)]$ $(p \equiv q) \equiv [(p \bullet q) \vee (\sim p \bullet \sim q)]$	Equiv.
18	Exportation	$[(p \bullet q) \supset r] \equiv [p \supset (q \supset r)]$	Exp.
19	Tautology	$p \equiv (p \vee p)$ $p \equiv (p \bullet p)$	Taut.

Appendix C

Notes and data files from the sessions of the connoisseur evaluation. The information is organized by date. Information from computer files is edited for clarity. Some text is copied directly from the screen of Peitho in operation but this was not done during the sessions. Note that displays of linearized graphs are selected to show the features most revealing for the example in question. Taken together they give some sense of the graph feature.

Wednesday, November 15

-spent 45 minutes demonstrating Peitho

-student user

-builder

We agreed to meet for the next three Wednesdays for him to learn the system.

Wednesday, November 22

notes re graph

-some way to show indenting levels - indent details

-change *role* to *element* or ...

-analysis features needed to be added

--

manipulation of program is fairly clear

Lance operated the program today, looking at two examples - sappho, and tanker. He had never used a mouse before so the major learning problem involved mastering the movement and clicking and dragging.

He did not have trouble navigating the various forms, becoming disoriented only concerning "backing out" of a few situations - e.g., the structural display screen, or an argument called from 'support' on another argument.

Next week - Nov. 29 - he will bring a short passage and try to create an argument structure from it.

Wednesday, December 6

discussed the connoisseur evaluation plan

-tried out system with a Sherlock Holmes deduction.

-flexibility of structure-

problem - form of argument missing

- want to put more than one item in [role]

--

program bug - critical note did not get included in structure graph!!

--

1 words reused in confusing fashion, e.g., 'analysis' in menu

2 need to work on features of graph - needs clarifying

file: holmes

text passage

"... You appeared to be surprised when I told you, on our first meeting, that you had come from Afghanistan."

"You were told, no doubt."

"Nothing of the sort. I *knew* you came from Afghanistan. From long habit the train of thoughts ran so swiftly through my mind that I arrived at the conclusion without being conscious of intermediate steps. There were such steps, however. The train of reasoning ran, 'Here is a gentleman of medical type, but with the air of a military man. Clearly an army doctor, then. He has just come from the tropics, for his face is dark, and that is not the natural tint of his skin, for his wrists are fair. He has undergone hardship and sickness, as his haggard face says clearly. His left arm has been injured. He holds it in a stiff and unnatural manner. Where in the tropics could an English army doctor have seen much hardship and got his arm wounded? Clearly in Afghanistan.' The whole train of thought did not occupy a second. I then remarked that you came from Afghanistan, and you were astonished."

"It is simple enough as you explain it," I said, smiling. (A. Conan Doyle, *A Study in Scarlet*, 1887, ch. 2. --Copi & Cohen, p.57, #30.)

statements

1. I knew you came from Afghanistan.
2. a gentleman of medical type
3. he has the air of a military man
4. He is an army doctor. **R**

[no evidence] Holmes is taking for granted that his readers would be familiar with the British campaign in Afghanistan.

5. He has just come from the tropics.

6. his face is dark

7. that is not the natural tint of his skin

8. his wrists are fair

9. He has endured hardship and sickness

10. his face is haggard

11. his left arm has been injured

12. arm is held stiffly and unnaturally

13. Where would all this be possible? R

This is a rhetorical question drawing together all aspects of the reasoning process thus far: the man is an army doctor, who has just come the tropics, and who has endured hardship, sickness, and injury. Well, of course, he has just come from Afghanistan.

arguments

generic Toulmin strategy 4, 5, 9, 11 -> 1 [roles not used]

generic Toulmin strategy 2, 3 -> 4

generic Toulmin strategy 6, 7, 8 -> 5 .

generic Toulmin strategy 10 -> 9

generic Toulmin strategy 12 -> 11

linearized graph

Analysis of Argument: d:\1peitho\holmes

. 1 I knew you came from Afghanistan.

. . 2 He is an army doctor.

. . . 3 a gentleman of medical type

. . . 3 - - - - - - - - - - - - - - - - - -

. . . 3 he has the air of a military man

. . 2 - - - - - - - - - - - - - - - - - -

. . 2 He has just come from the tropics.

. . . 3 his face is dark

. . . 3 - - - - - - - - - - - - - - - - - -

. . . 3 that is not the natural tint of his skin

. . . 3 - - - - - - - - - - - - - - - - - -

. . . 3 his wrists are fair

. . 2 - - - - - - - - - - - - - - - - - -

. . 2 He has endured hardship and sickness

. . . 3 his face is haggard

. . 2 - - - - - - - - - - - - - - - - - -

. . 2 his left arm has been injured

. . . 3 arm is held stiffly and unnaturally

. 1 Where would all this be possible?

Friday, December 15

annis, jones

Wednesday, December 20

- introduced the authoring environment

  - looked at existing model (Missimer) and a bare one - ready to start.

Monday, January 15

Lance here, doing first builder model

1 Conflicting use of terminology. Terms like argument are specific in Peitho but may (will) conflict with the use of same terms in a particular example

2 We discussed the use of 'premise' and 'conclusion' as the only "roles" in Copi and Cohen in the first chapter.

Lance had read passages from my thesis but we still had to discuss the fit. The proper use of "argument" (== chain of reasoning) had to be clarified.

We started by sketching a few roles and me proposing some simple argument strategies. We discussed his "answers" to some Copi exercises as examples and took the single step argument examples as the place to find the strategy templates.

In a first attempt at defining roles, Lance included "premise indicators" and "conclusion indicators" as roles. (I feel these should be in analysis or in the 'contents' (or maybe evidence types if stretched).

(We played a little with the custom colours. Ended up with about 6-8 (check this) roles. incl. indicators above.)

He wanted to do example arguments but we must do strategies first.

strategies 1 - simple argument, 2 - convergent argument, 3 - divergent argument [sketches in notes]

In doing simple argument I had to review that the claim/conclusion of the argument is the node already on the strategy.

He included divergent argument [sketch] although it "strictly" should be a pair of simple arguments supporting the same claim. [sketch]

In the convergent model, it looked like a link from a link would be useful. Lance added another role instead: conjunctive premise. [sketch]

After session - 3:00 PM

-conflicts I've noticed with "my" vision:

-the divergent strategy

-the "premise indicators" as roles

-distinction of strategies based on enthymemes (implied statements) - I don't think these are necessary.

Wed 19 we will try some example arguments and do revisions - feedback loop.

file: copil Builder files

[roles and strategies only - no analysis notes]

evidence

[none]

roles

premise

A premise is a statement which is used to support a claim.

conclusion

A conclusion is the claim which is inferred from one or more premises.

sub-conclusion

A sub-conclusion is a statement which is inferred from another statement or set of statements, but which in turn serves as a premise in an extended chain of reasoning.

explanation

An explanation is not part of the chain of reasoning, but it may serve to clarify one of the other statements. Explanations are often confused with arguments.

premise indicator

Certain words will often indicate that what follows is a proposition which will be used as a premise.

conclusion indicator

Certain words will signify that what follows is a claim. For our purposes, a conjunctive premise is one which conjoins the premises in a convergent argument.

enthymeme

An enthymeme is an incomplete chain of reasoning where a statement or statements is implied but not stated. The statement that is "suppressed" should be articulated to complete the chain.

conjunctive premise

For our purposes, a conjunctive premise is one which conjoins the premises in a convergent argument.

strategies

simple argument

For our purposes, a simple argument will involve one premise from which the conclusion is said to follow. Indicator terms may or may not be present.

premise-conclusion

divergent argument

A divergent argument is one in which the claim is supported by two premises each of one can establish the claim independently.

premise-conclusion

premise/

convergent argument

An argument in which the claim is supported by two (or more) premises taken together is said to be convergent. In the example two premises, taken together, lead to the conclusion--this is indicated by an intermediate premise which is a conjunction of the initial two premises.

premise-conjunctive premise - conclusion premise/

enthymematic argument

Either a premise or the conclusion is not articulated as it is understood to be implied.

enthymeme -> conclusion

(conjunctive premise unused)

Wednesday, January 17

doing some examples

-Lance says he will - later - revise some of the templates.

a bit of review on using Peitho as user/learner

-the entry of statements was awkward as he wanted to edit one and had to leave 'add' then click on it -> the commands were confusing (cancel, delete, update) in that context.

-first e.g. Copi, p. 53-4, #20

The use of the argument template was unclear - he created a couple of arguments in support of 2 statements but then went back to the statements.

I reminded him of making an argument structure.

The argument structure showed a lack of flexibility

-2 facts in a node

-clumsiness of moving around forms and modes

The conjunction node in the conjunction argument caused difficulties (no two facts in a node started it)

-> led to a new statement (5) which was half way between instructor and user roles - it described the structure, not the content.

Lance made an external support for the new statement which was context-based.

**-need to fix struct evaluation form and to highlight major claim [checked as done]

-looked at structure analysis (see previous note) then the statement analysis - Lance added some notes in the statement window

*-needs some better indicator of what statement is being commented on - (add to detail window on grid?)

BUT - the comments are great!!

-some comments are getting more like comments on the argument but

file: szasz

text passage

A disease entity is defined by signs and symptoms generated by objective - that is, organic - determinants. Thus ... illness is organic. Since mental disturbances are not organic, mental illness is not illness. (Dr. Thomas Szasz -- Copi & Cohen, p. 53-4, #20)

uses copi1

statements

1. Defining disease is organically based. R

A disease entity is defined by signs and symptoms generated by objective (organic) determinants.

Support: Thomas Szasz would have to provide some grounds for making this assertion.

2. Illness is organic. A

Illness is organic.

Statement Analysis:

Does the organic include the whole sphere of the mental? Is Szasz an identity theorist? (An identity theorist is someone who considers the mind and brain to be identical, i.e., the brain is the mind.)

3. Mental disturbances are not organic. R

Support: A reference to psychiatric literature and psychometric practices might be helpful to establish this statement.

Statement Analysis:

Mental disturbances are never organic? What if someone has been hit on the head?

4. Mental illness is not illness. A

Statement Analysis:

This seems rather too self-contradictory; another formulation might be helpful. He seems to mean that mental illness is not organic. What grounds does he have for claiming that only somatic disturbances can be considered illness?

5. Conjunction of 2 and 3 R

In an argument where two nodes of reasoning are brought together in order to arrive at the conclusion, the end claim of each node can be conjoined to give a conjunctive premise. This indicates the CONVERGENCE of the nodes.

Support: Illness is organic AND mental disturbances are not organic.

Statement Analysis:

Notes on statement 1: Perhaps one or two examples would be appropriate in order to illustrate what type of "sign" or "symptom" is relevant. What does Szasz mean by an "organic determinate," things like rashes, swellings, blood loss, etc.?

arguments

simple argument: 1->2

convergent argument:
```
2 - 5 - 4
3 /
```

linearized graph

Analysis of Argument: d:\1peitho\jan17\szasz

. 1 Mental illness is not illness.

. . 2 Mental disturbances are not organic.

. . 2 ------------------

. . 2 Illness is organic.

. . . 3 Defining disease is organically based.

. . 2 ------------------

. . 2 Conjunction of 2 and 3

Wednesday, January 24

Lance could not stay today. He did mention that a way to look at different arguments in a claim at the same time would be useful.

-it is logically already there but window manipulation is too clumsy to make it useful.

-

I tried a version of Nassi-Schneidermann diagrams as an example (code statements as evidence types)

1 - this really shows the need for putting meaning on links in the strategies for intelligent sequencing in the linearized displays. e.g. - sequence control structure needs to have statements in order

2 - also shows need for user control of strategy format (case statement: change number of statements and sequence: how many statements)

[This could lead to an extended power for the creative user?]

Wednesday, January 31

Lance came ready to alter the strategies. He was unhappy with the meta-statement in the szasz argument and returned to builder mode to extend the role set. "Hypothetical statement" (or inference role as I would call it) has form:

if (antecedent) then (consequent) !!

and conjunction as compound statement - interesting notions - there is a stretching of the role notion with these definitions - I guess a conjunction would be a 'claim' of a three element strategy == and gate but his structure allows a reduction in number of arguments I think - an excellent example of a non-supported role.

Also adding negation - this is getting like prog.

I had to remind Lance that the roles had to be built into strategies to be useful. He opened strategy and while creating new ones, did the colours on the roles which he had neglected. He created a "disjunctive syllogism" - very nice.

```
(A\/B)^~B -> A.
```

and "hypothetical syllogism" (transitive)

```
(A->B)^(B->C)  [ ->  (A->C) ?  ]
```

He is still struggling with the interface in making strategies, esp. the manipulation of roles.

We discussed an interesting problem with hypothetical syllogism- all 3 roles are "hypothetical propositions" so the structure is not very enlightening. We really want to see

```
A->B

B->C
```
[as titles on the roles in the strategy/arg]

```
A->C
```

but the compound statements don't allow this. Using separate statements for A, B, C etc. doesn't answer the problem.

I suggested "hyp.prop A->B",

"hyp.prop A->B",

"hyp.prop A->B", as titles.

Lance is now experimenting with distinct versions of roles - antecedent I, antecedent II, etc.

[sheet of notes made by Lance on Jan. 31]

roles

[added to previous copi1 set]

disjunction

A premise which is joined by the connective 'or' ('either/or', 'unless')--each part of the premise is a disjunct.

hypothetical proposition

An hypothetical or conditional statement is of the form: if (antecedent), then (consequent). The hypothetical premise is not asserting that the antecedent is true, nor is the consequent being affirmed, thus, the statement can not be broken up into its components.

conjunction

A compound statement of two or more simpler statements joined by the connective 'and' ('but', 'however', etc.). Conjunctions can be broken down into their components since the components are being asserted.

negation

A statement which is the denial of another statement.

hypothetical major

none defined

hypothetical minor

hypothetical conclusion

antecedent I

antecedent II

antecedent III

consequent I

consequent II

consequent III

strategies

disjunctive syllogism

Such an argument occurs when one of the premises is a disjunction and the other premise is a negation of one of the disjuncts. The conclusion will be the other disjunct.

`disjunction - negation -> conclusion`

hypothetical syllogism

This argument occurs where the two premises are conditional statements: the consequent of the first statement will be the antecedent of the second premise. The conclusion will also be a conditional statement, having as its antecedent the first premise's antecedent and the second premise's consequent for its consequent.

```
antecedent I - consequent III - hypothetical major
consequent III - consequent II - hypothetical minor
antecedent I         -hypothetical conclusion
```

modus ponens

hypothetical proposition - antecedent I - conclusion

Wednesday, February 7

discussed the 'grain size' issue which is just a schematic rep. problem (i.e., for clarification, not real) - it does imply some features for a redesign of the system however.

New example - Copi #12, p.52 - Bertrand Russell

[sketch - copy from Lance's Copi] <- Lance's marginal sketch

small error: it appears on updating an argument - it showed add/delete

an extraneous statement showed the use of the warnings - it was both unused and a multiple claim.

The statement from Lance's view was extraneous. So, this was crude but OK!!

We discussed the need to allow multiple conclusions from a chain of argument (I allow it but with a possible warning)

Lance used extra statement not from the text to fill out the argument strategy form (conjunctive premise) - he made the statements 'conjunction A', 'conjunction B'

He is getting better but still having trouble with the operation of the program.

Note - where do argument details get included in the graph? They are not showing up - see the argument in support of []

Need more flexibility in using "details" in the arguments.

e.g. 'conjunction A' had details about the two statements to put together - Lance wanted to include the details in the role box.

Completed. Go on to a new example.

Copi, p.309,#27 - Bacon - an invalid argument.

This led to a need for another strategy which was not in the Copi set. Instead of leaving to redo in builder mode, he decided to use convergent argument and add notes.

(here the argument content details showed up OK!!)

We saved this as Bacon

-

Into builder files-

need for better access to list of roles - it's too big to see all by scrolling - wants a hard copy but something on line is needed too.

-> a scaling up problem!!

-

still some difficulties with building strategies - op. details.

Lance says he now needs to rethink the roles needed - (some can be removed probably)

-added modus ponens to Copi1 set

[sketch of the AI model of modus ponens as used in thesis footnote]

Lance is ready to think about redesign from new knowledge of how system works.

file: russell

text passage

Does the past exist? No. Does the future exist? No. Then, only the present exists. Yes. But within the present there is no lapse of time? Quite so. Then time does not exist? Oh, I wish you wouldn't be so tiresome. (Bertrand Russell --Copi & Cohen, p.52, #12.)

[uses copi1 (without modus ponens added)]

statements

1. Does the past exist? No.
2. Does the future exist? No.
3. Then only the present exists. Yes. A
4. No lapse of time in the present.

   But within the present there is no lapse of time? Quite so.

5. Then time does not exist? A
6. Oh, I wish you wouldn't be so tiresome. A
7.

8. Conjunction A

The past does not exist AND the future does not exist.

9. Conjunction B

Only the present exists AND there is no lapse of time in the present.

arguments

convergent argument: 1 - 8 - 3

2 /

The conjunctive premise indicates that both premises are necessary for the conclusion.

convergent argument: 3 - 9 - 5

4 /

no strategy 6

This statement is superfluous to the actual argument in the passage; it functions more or less rhetorically. To deny that time does not exist is almost ridiculous, isn't it?

linearized graph

Analysis of Argument: d:\1peitho\feb07\russ

. 1 Then time does not exist?

. . 2 Then only the present exists. Yes.

. . . 3 Does the past exist? No.

. . . 3 - - - - - - - - - - - - - - - - - -

. . . 3 Does the future exist? No.

. . . 3 - - - - - - - - - - - - - - - - - -

. . . 3 Conjunction A

. . 2 - - - - - - - - - - - - - - - - - -

. . 2 No lapse of time in the present.

. . 2 - - - - - - - - - - - - - - - - - -

. . 2 Conjunction B

. 1 Oh, I wish you wouldn't be so tiresome.

. 1

linearized graph

Analysis of Argument: d:\1peitho\feb07\russ

. 1 Then time does not exist?

. . 2 [Convergent Argument]

. . 2 Then only the present exists. Yes.

. . . 3 [Convergent Argument]

. . . 3 Does the past exist? No.

. . . 3 Warning: there is no support for this claim

. . . 3 - - - - - - - - - - - - - - - - - -

. . . 3 Does the future exist? No.

. . . 3 Warning: there is no support for this claim

. . . 3 - - - - - - - - - - - - - - - - - -

. . . 3 Conjunction A

. . . 3 Warning: there is no support for this claim

. . 2 - - - - - - - - - - - - - - - - - -

. . 2 No lapse of time in the present.

. . 2 Warning: there is no support for this claim

. . 2 - - - - - - - - - - - - - - - - - -

. . 2 Conjunction B

. . 2 Warning: there is no support for this claim

. 1 Oh, I wish you wouldn't be so tiresome.

. . 2 [No strategy]

. 1

Warning: this statement is unused

Warning: there are multiple claims.

file: bacon

text passage

And certainly if its essence and power are infinite, its goodness must be infinite, since a thing whose essence is finite has finite goodness. (Bacon --Copi & Cohen, p.309, #27.)

statements

1.If essence is finite, goodness is finite.

This statement refers to any thing: If 'x' is finite, then 'x' has finite goodness.

2. The essence of this thing is not finite.

3. The goodness of this thing is not finite. A

arguments

convergent argument: 1-{ }-3
2/

This is argument is a mixed hypothetical syllogism, and is invalid: Roger Bacon denies the antecedent of the hypothetical, and this is, of course, fallacious: THE FALLACY OF DENYING THE ANTECEDENT.

linearized graph

Analysis of Argument: c:\1peitho\feb07\bacon

. 1 The goodness of this thing is not finite.

. . 2 If essence is finite, goodness is finite.

. . 2 - - - - - - - - - - - - - - - - - -

. . 2 The essence of this thing is not finite.

Wednesday, February 14

-we discussed the hypothetical syllogism (transitive (A->B, B->C=>A->C)

It is OK but the "B" commonality cannot be shown tho' it can be described in the strategy text.

Today, Lance want to distinguish deductive and inductive reasoning then do a strategy set on each. He's doing one further example with Copi1 then we'll discuss it.

Example: Copi, p.399, #18 - a deductive argument.

He put in statements then wanted to add the complete text, so I suggested putting it into the 'context' analysis box.

His intuitions are getting better about the program - correctly identifying the 'external support' requirements for facts 1,2,3.

One statement (#6) contained "unless". (He mentionea students were having difficulty distinguishing content from structure but this implies he is also?) Ha! - he just now saw the problem and edited out the 'unless'!

He is entering as statements, structural items.

(e.g., 8, although #1, #2 and #3)

I am itching to structure the argument with a strategy instead!

Lance is now structuring the argument but maybe I should try it as an example.

(This system may in fact be a better way!) -> What strategies will I need. Maybe something intermediate is required. (saved as WHO)

Lance is going to design some deductive strategies based on Copi's rules of inference + replacement. Perfect!!

I will do the same and we will compare and discuss.

I claim this exercise will help him clarify the content/structure distinction that he said the students have trouble with. It concretizes that difference!!

I'll use his e.g. here as my thesis demo if it works out.

[page of notes from Feb. 14]

file: who

text passage

Although world population is increasing, agricultural production is declining and manufacturing output remains constant. If agricultural production declines and world population increases then either new food sources will become available or else there will be a radical redistribution of food resources in the world unless human nutritional requirements diminish. No new food sources will become available, yet neither will family planning be encouraged nor will human nutritional requirements diminish Therefore there will be a radical redistribution of food resources in the world. (W, A, M, N, R, H, P). (Copi & Cohen, p.399, #18.)

statements

1. World population is increasing. R

   Support: (no evidence) Statistics (Reference: United Nations demographics)

2. Agricultural production is declining. R

   Support: () Statistics (longitudinal studies)

3. Manufacturing output remains constant. **R**

Support: () Statistics.

4. New food sources will become apparent. **R**

Support: () Expert projections (futurology)

5. There will be radical redistribution of food resources. **R**

Support: () Possible future (think tank)

6. Human nutritional requirements diminish. **R**

Support: () Expert projections (possible scenarios. . .)

7. Family planning will be encouraged. **R**

Support: () Projections.

8. Although #1, #2 and #3.

Although world population is increasing, agricultural production is declining and manufacturing output remains constant.

9. If #2 and #1, then #4 or (#5 or #6).

If agricultural production declines and world population increases then either new food sources will become available or else there will be a radical redistribution of food resources in the world unless human nutritional requirements diminish.

10. No #4.

No new food sources will become available. . .

11. Yet neither #7 nor #6.

, , ,yet neither will family planning be encouraged nor will human nutritional requirements diminish.

12. Therefore #5.

Therefore there will be a radical redistribution of food resources in the world.

context analysis note

Notes about the whole argument: (complete actual text)

Although world population is increasing, agricultural production is declining and manufacturing output remains constant. If agricultural production declines and world population increases then either new food sources will become available or else there will be a radical redistribution of food resources in the world unless human nutritional requirements diminish. No new food sources will become available, yet neither will family planning be encouraged nor will human nutritional requirements diminish. Therefore there will be a radical redistribution of food resources in the world.

arguments

none

NOTE: context analysis note is not included in structure graph***

Wednesday, February 28

-he stated he realized he had not built a complete set of connectives so we went into the builder mode to make changes.

-he deleted some roles.

-went to the 'who' example and deleted the 'category error' statements which are, in fact, arguments (this version of 'who' is saved)

Now he is starting a new version of the same (p.399,#8) based on reduced set from above. (still some problems in using the input window)

The first real bound on the system showed up in the logic reps -> because deductive argument is structure-driven!! so there are tautologies!! which means compound conclusions!

(I think the negative will cause problems too!)

We are now re-entering the problem based on first the single statements then , using 'compound statement to rep the right side' of the necessary tautologies.

future_2.*

future_3.*

I am going to make a copy of the inferences and tautologies of the Copi book and we'll try again.

file: copi1

roles same as original except

Conclusion indicators

Certain words will signify that what follows is a claim. [altered definition]

Antecedent [replaces I, II, III]

Consequent [replaces I, II, III]

strategies same as original except

hypothetical syllogism [errors in role definition?]

file: future_2 reduced version of **who** discussed above

statements

2. World population is increasing.
3. Agricultural production is declining.
4. Manufacturing output is constant.

5. New sources or redistribution or less.

If agricultural production declines and world population increases then either new food sources will become available or else there will be a radical redistribution of food resources in the world unless human nutritional requirements diminish.

6. No new sources, no f. planning, not less

No new food sources will become available, yet neither will family planning be encouraged nor will human nutritional requirements diminish.

7. Therefore radical redistribution

Therefore there will be a radical redistribution of food resources in the world.

[No other development]

file: future_3 revised version of who, future_2

statements

1. W: world population is increasing.
2. A: agricultural production is declining.
3. M: manufacturing output is constant.
4. N: New food sources
5. R: redistribution of food resources
6. H: nutritional requirements diminish
7. P: family planning is encouraged
8. If A and W, then either N, or R or H
9. Not N and not either P or H

[no further development]

Wednesday, March 6

Looking at my Copided files

- new names ~~false~~ - negative

- problems with implication box - need variations

roles logically structured the same do not play same 'role' in strategy

e.g. `x->y \/ p->q`

`x\/p -> y\/q`

-we created 'negated proposition' in

`p->q ^ ~q => ~p`

changed 'false precondition' to 'negated antecedent'

and added negated consequent (to replace conclusion)

-note change in modus ponens box:

```
p->q

p

------

q
```

-apply to others also. (other strategies)

Now we're doing the food example again!

Lance is entering all the statements of his deductive module

-we put in all the arguments fine

The strategy graph looks pretty good especially with *strategies* turned on.

Now we are doing p.399, #15 - Moses - with words for basic statements and references for the logical constructs. We've used numbers but I think we'll change to letter codes. (as in text) Using the actual text in the detail box for cryptic statements works well, e.g., If M then C

Instead of 'preplanning' the argument he is trying to 'build' it in the system (had started on paper but I suggested looking at structure in the system.)

-

We've done the "R"s and are now on paper - doing the deductive argument.

This time there are tautologies to try.

->the one way tautology `A->B  =>  !A\/B` was OK but lucky!!

The other one is not - it is the reverse of the above.

[notes from March 6 - Moses, 2 pages plus questions]

file: copided

roles

implication (p -> q)

if p then q

p	q	p->q
T	T	T
T	F	F
F	T	T

F	F	T

proposition

A statement which may be true or false. When a statement is treated as a proposition, its internal structure is not at issue; it may be simple or complex.

conclusion

A statement established by a deductive argument. It may be simple or complex.

Negated Antecedent

A proposition shown to be false because it implies a statement which is known to be false.

disjunction ($p \vee q$)

A disjunction is a union of two propositions. If either or both of the propositions are true, the disjunction is true.

p	q	p∨q
T	T	T
T	F	T
F	T	T
F	F	F

conjunction (p^q)

A conjunction is the intersection of two propositions. It is true only if both propositions are true.

p	q	p^q
T	T	T
T	F	F
F	T	F
F	F	F

false conjunction ~(p^q)

a false conjunction is true unless both of the propositions are true

false disjunction $\sim(p \vee q)$

the false disjunction is true when both the propositions are false

conjunct of false $(\sim p \wedge \sim q)$

this formula is true only if both its propositions are false.

disjunct of false $(\sim p \vee \sim q)$

this disjunction is true unless both its propositions are true

equivalence $(p = q)$

Two propositions are equivalent when both are true or both are false

negated proposition

negated consequent

note about roles

This set of roles represents simple propositions containing one concept and also compound propositions which contain two concepts with a logical link between them.

Be sure that the statements associated with the roles fit the logical form. Notice that a compound statement can be associated with a simple proposition.

strategies

Modus Ponens

If a proposition is known to be true, the implication establishes that the conclusion is also true. For example,

p -> q

p

------

q

Hypothetical syllogism

(p1->p2) ^ (p2->p3)

-> (p1->p3)

The hypothetical syllogism applies to two implications only if the conclusion (p2) of the first is the same proposition as the precondition of the second. The resulting implication links the first precondition (p1) with the final conclusion (p3).

Modus Tollens

If an implication (p->q) establishes a proposition q which is known to be false, then the precondition, p is also false.

i.e., ~q ^ (p->q) -> ~p

Disjunctive syllogism

If a disjunction (p∨q) is known to be true but one of its component propositions (p) is known to be false then the other (q) must be true.

Constructive Dilemma

If two implications, (p1->p2) and (p3->p4), not necessarily related, are established then if one or the other of the preconditions (p1∨p3) is established then one of the conclusions must be true (p2∨p4).

Absorption

If p1 implies p2 (p1->p2) then knowing p1 to be true implies that the conjunction (p1^p2) is true.

(p1->p2)

-> (p1->(p1^p2))

Simplification

If a conjunction (p1^p2) is known to be true, then it follows that both propositions (p1 and p2) are true individually.

(p1^p2) -> p1

(p1^p2) -> p2

Conjunction

A conjunction is true only if its component propositions are true.

Addition

A disjunction is true if one of its propositions is true. The truth value of the other proposition does not matter then.

$p1 \rightarrow (p1 \vee p2)$

DeMorgan - not both

TAUTOLOGY

$\sim(P1 \wedge P2) = (\sim P1 \vee \sim P2)$

This equivalence can be used for substitution in either direction.

DeMorgan neither

TAUTOLOGY

$\sim(P1 \vee P2) = (\sim P1 \wedge \sim P2)$

This equivalence can be used for substitution in either direction.

Transposition

TAUTOLOGY

$(P1 \rightarrow P2) = (\sim P2 \rightarrow \sim P1)$

If

P1 implies P2

then, equivalently,

$\sim P2 \rightarrow \sim P1$

Material Implication

TAUTOLOGY

$(P1 \rightarrow P2) = (\sim P1 \vee P2)$

An implication is equivalent to a disjunction with the precondition predicate negated.

Material Equiv. (Imply)

TAUTOLOGY

[(P1->P2)^(P2->P1)] = (P1=P2)

If two propositions imply each other then they are equivalent. Conversely, equivalence implies mutual implication also.

Material Equiv. (Match)

TAUTOLOGY

(P1 = P2) = (P1^P2) V (~P2 ^ ~P1)

If two propositions are both true or both false then they are equivalent; conversely, if they are equivalent then they are both true or both false.

file: dedfood repeat of **who** using **copided**

statements

1. W ^ (A ^ M)	R	
2. (A ^ W) -> [(N V R) V H]	R	} no evidence in forms
3. ~N ^ (~P ^ ~H)	R	
4. R	A	
5. A ^ W	A	
6. (N V R) V H	A	
7. ~N	A	
8. R V H	A	
9. ~P ^ ~H	A	
10. ~H	A	

arguments:

4. disjunctive syllogism:	8 - 4
	10/
5. simplification:	1 - 5
6. modus ponens:	2 - 6

	5 /
7. simplification:	3 - 7
8. disjunctive syllogism:	6 - 8
	7 /
9. simplification:	3 - 9
10. simplification:	9 - 10

linearized graph

Analysis of Argument: d:\1peitho\mar06\dedfood

. 1 R

. . 2 R V H

. . . 3 (N V R) V H

. . . . 4 (A ^ W) -> [(N V R) V H]

. . . . 4 - - - - - - - - - - - - - - - - - -

. . . . 4 A ^ W

. . . 3 - - - - - - - - - - - - - - - - - -

. . . 3 ~N

. . . . 4 ~N ^ (~P ^ ~H)

. . 2 - - - - - - - - - - - - - - - - - -

. . 2 ~H

. . . 3 ~P ^ ~H

. . . . 4 ~N ^ (~P ^ ~H)

linearized graph (structural parts and strategy names)

Analysis of Argument: d:\1peitho\mar06\dedfood

. 1 Thesis of the argument: R

. . 2 [Argument: Disjunctive syllogism]

. . 2 Claim: R V H

. . . 3 [Argument: Disjunctive syllogism]

. . . 3 Claim: (N ∨ R) ∨ H

. . . . 4 [Argument: Modus Ponens]

. . . . 4 Claim: (A ^ W) -> [(N ∨ R) ∨ H]

. . . . 4 - - - - - - - - - - - - - - - - - -

. . . . 4 Claim: A ^ W

. . . 3 - - - - - - - - - - - - - - - - - -

. . . 3 Claim: ~N

. . . . 4 [Argument: Simplification]

. . . . 4 Claim: ~N ^ (~P ^ ~H)

. . 2 - - - - - - - - - - - - - - - - - -

. . 2 Claim: ~H

. . . 3 [Argument: Simplification]

. . . 3 Claim: ~P ^ ~H

. . . . 4 [Argument: Simplification]

. . . . 4 Claim: ~N ^ (~P ^ ~H)

file: moses

text passage

If the Mosaic account of the cosmogony is correct, the sun was not created till the fourth day. And if the sun was not created till the fourth day, it could not have been the cause of the alternation of day and night for the first three days. But either the word "day" is used in Scripture in a different sense form that in which it is commonly accepted now or else the sun must have been the cause of the alternation of day and night for the first three days. Hence it follows that either the Mosaic account of the cosmogony is not strictly correct or else the word "day" is used in Scripture in a different sense from that in which it is commonly accepted now. (M, C, A, D) (Copi & Cohen, p.399, #15, Moses.)

statements

1. Mosaic cosmogony is correct. (M)
2. Sun was not created until day 4. (C)
3. 1st 3 days sun didn't cause change (A)
4. 'Day' is used in a different way. (D)
5. If M, then C. R [not defined]

   If the Mosaic account of the cosmogony is strictly correct, the sun was not created till the fourth day.

6. And if C, then A. R [not defined]

   And if the sun was not created till the fourth day, it could not have been the cause of the alternation of day and night for the first three days.

7. Either D or not A. R [not defined]

   But either the word 'day' is used in Scripture in a different sense from that in which it is commonly accepted now or else the sun must have been the cause of the alternation of day and night for the first three days.

8. Hence either not M or D. A

   Hence it follows that either the Mosaic account of the cosmogony is not strictly correct or else the word 'day' is used in Scripture in a different sense from that in which it is commonly accepted now.

9. If M, then A. A
10. If A, then D. A
11. If M, then D. A

arguments

material implication: 11 - 8

hypothetical syllogism: 5 - 9

6 /

material implication: 7 - 10

hypothetical syllogism: 9 - 11

10/

linearized graph

Analysis of Argument: d:\1peitho\mar06\moses

. 1 Mosaic cosmogony is correct. (M)

. 1 Sun was not created until day 4. (C)

. 1 1st 3 days sun didn't cause change (A)

. 1 'Day' is used in a different way. (D)

. 1 Hence either not M or D.

. . 2 If M, then D.

. . . 3 If M, then A.

. . . . 4 If M, then C.

. . . . 4 - - - - - - - - - - - - - - - - - -

. . . . 4 And if C, then A.

. . . 3 - - - - - - - - - - - - - - - - - -

. . . 3 If A, then D.

. . . . 4 Either D or not A.

linearized graph (with warnings)

Analysis of Argument: d:\1peitho\mar06\moses

. 1 Mosaic cosmogony is correct. (M)

Warning: this statement is unused

. 1 Sun was not created until day 4. (C)

Warning: this statement is unused

. 1 1st 3 days sun didn't cause change (A)

Warning: this statement is unused

. 1 'Day' is used in a different way. (D)

Warning: this statement is unused

. 1 Hence either not M or D.

. . 2 [Material Implication]

. . 2 If M, then D.

. . . 3 [Hypothetical syllogism]

. . . 3 If M, then A.

. . . . 4 [Hypothetical syllogism]

. . . . 4 If M, then C.

. . . . 4 - - - - - - - - - - - - - - - - - -

. . . . 4 And if C, then A.

. . . 3 - - - - - - - - - - - - - - - - - -

. . . 3 If A, then D.

. . . . 4 [Material Implication]

. . . . 4 Either D or not A.

. . . . 4 Warning: Basis fact missing for role proposition

. . . . 4 Warning: Basis fact missing for role proposition

. . 2 Warning: Basis fact missing for role proposition

. . 2 Warning: Basis fact missing for role proposition

Warning: there are multiple claims.

Wednesday, March 13

Observation - re tautologies ->

make one each direction and improve the arrow links to show the implication.

Material implication

[sketch]

-

The attempt to support either D or not A led to []

As a result of the analysis now in Moses, we are going to look further at the evidence

- this will be added to "copided" and saved as "copide2"

I'll fix the copide2 into the Moses example.

file: copide2

evidence

assertion

A claim made by an individual for which no evidence is provided directly.

observation

reference to a state of affairs--a factual claim.

authority (expert)

The claim that someone who is "in the know" would assert to be the case. This is usually legitimate although the fallacy ad verecundiam occurs if the individual referred to has no real grounds to be considered an expert in a particular field.

statistical data

textual reference

quotation or paraphrase

experimental programmes

values

conventions

some disciplines have ground rules, accepted axioms, etc.

emotional appeal

acceptance for sake of arg

file: moses

statements (contents as before)

1. R

   Support: This is a believer's claim: the Bible is understood as providing explanation in line with modern scientific methods.

2. R

   Support: Cf. Genesis 1-2

3. R

   Support: Again, if we are taking the text at face value, we have a problem: how can an alternation between day and night occur without the presence of the sun?

4. R

   Support: There are other passages in the Bible where it is pointed out that a day for the Lord is a thousand years for us. Is 'day' being used analogically?

5. R

   Support: Account of creation in GENESIS

6. R

   Support: Textual reference: in Genesis 1 the sun is not present in the cosmos until day 4 which makes it peculiar that we have three 'days' prior during which there is alternation spoken of between day and night, or could this be a misreading?

7. R

   Support: None defined

8. A
9. A
10. A

11. A

arguments

material implication: 1,4--11 - 8

hypothetical syllogism: 5 - 9

6 /

material implication: 3,4--7 - 10

hypothetical syllogism: 9 - 11

10/

linearized graph (with warnings)

Analysis of Argument: d:\1peitho\mar13\moses [warnings on]

. 1 Sun was not created until day 4. (C)

Warning: this statement is unused

. 1 Hence either not M or D.

. . 2 If M, then D.

. . . 3 If M, then A.

. . . . 4 If M, then C.

. . . . 4 - - - - - - - - - - - - - - - - - -

. . . . 4 And if C, then A.

. . . 3 - - - - - - - - - - - - - - - - - -

. . . 3 If A, then D.

. . . . 4 Either D or not A.

. . . . 4 - - - - - - - - - - - - - - - - - -

. . . . 4 1st 3 days sun didn't cause change (A)

. . . . 4 - - - - - - - - - - - - - - - - - -

. . . . 4 "Day" is used in a different way. (D)

. . 2 - - - - - - - - - - - - - - - - - -

. . 2 Mosaic cosmogony is correct. (M)

. . 2 - - - - - - - - - - - - - - - - - -

. . 2 "Day" is used in a different way. (D)

Warning: there are multiple claims.