Supporting acquisition of visual diagnostic expertise: Case-Based Training to Intelligent Tutoring

Rebecca Crowley, MD, MS

Assistant Professor, Center for Pathology Informatics

crowleyrs@msx.upmc.edu

http://health.pitt.edu/users/rebecca

University of Pittsburgh School of Medicine
Center for Pathology Informatics

Interests

- Knowledge representation
- Education
- AI applications in Education
- Human Computer Interaction
- Intelligent Multimedia Interfaces
- And also … Virtual Slides

Overview

- How do we build effective educational systems that incorporate new technologies such as Virtual Slides?
- Two examples from our laboratory that take very different approaches. Both of these systems are very early examples!
- Both grounded on results of our empirical work describing the development of expertise in this domain – How does this work help inform system design?
- Virtual Slide Set - A case-based system for authoring and presentation of Virtual Slides
- SlideTutor - An intelligent tutoring system
- Demonstrations
- Future Questions

Approach

- Medical education is “stuck” in time and space and content (Friedman, 2000)
- Apprenticeship model is increasingly hard to sustain
- Many environments, new pressures, need to cover more material in less time
- Create computer-based methods for training
- Make environments realistic – Virtual Slides
- Identify where students have problems and where traditional approaches have failed
- Look to other fields for ideas
- Evaluate the results of our work

A Study of Expertise in Visual Diagnosis

Motivation

- Understand a difficult diagnostic task that requires multiple kinds of skills
- Investigate how pathologists develop the ability to classify complex visual patterns
- Apply findings to the design of image-based computer training systems

Background

- Numerous previous studies of expertise in medical domains that are not primarily visual (Patel, Bordage)
- Several previous studies of expertise in radiology and dermatology (Lesgold, Kundel, Norman)
- No previous studies of expertise in microscopic diagnosis
- Microscopic diagnosis may be quite different

Methods

- Think-aloud protocols
- Videotape collected from the microscope
- Determine accuracy – specific and categoric
- Code processes (operators) and content (knowledge states) using process coding scheme - 48 codes
- Identify errors using error coding scheme - 8 codes
- Measure times to important events
- Aggregate and compare codes and times for level, or case
- ANOVA, Scheffe tests to measure differences

Cases & Subjects

- Standardized set of cases in breast pathology
- 10 Novices – just finished year 2
- 10 Intermediates – 2nd and 3rd year residents
- 8 Experts – Attending pathologists with >10 years experience

Data Collection

Standardized Case Set

Case	Gold Standard Diagnosis	Description
1	Infiltrating Ductal Carcinoma	Focal lesion of poorly differentiated cancer adjacent to biopsy site and scar.
2	Ductal Carcinoma in Situ (DCIS)	Widespread solid and cribriform in-situ carcinoma present throughout majority of sample.
3	Infiltrating Lobular Carcinoma	Widespread classical type infiltrating lobular carcinoma. Scant adjacent normal tissue.
4	Lobular Carcinoma in Situ (LCIS)	Small focus of LCIS with retrograde extension in otherwise normal breast.
5	Fibroadenomas, Sclerosing Adenosis and Intraductal Papilloma	Multiple focal lesions, including sclerosing adenosis - a benign lesion that shares some visual features with cancer.
6	Paget's Disease	Nipple with focal area of intra-epidermal Paget's disease. No underlying carcinoma.
7	Adenomyoepithelioma	Small circumscribed lesion with uniform features.
8	Atypical Papilloma	Large lesion with numerous atypical features

Crowley et al. JAMIA, in press

An example protocol: An expert diagnosing DCIS

Expert E7:

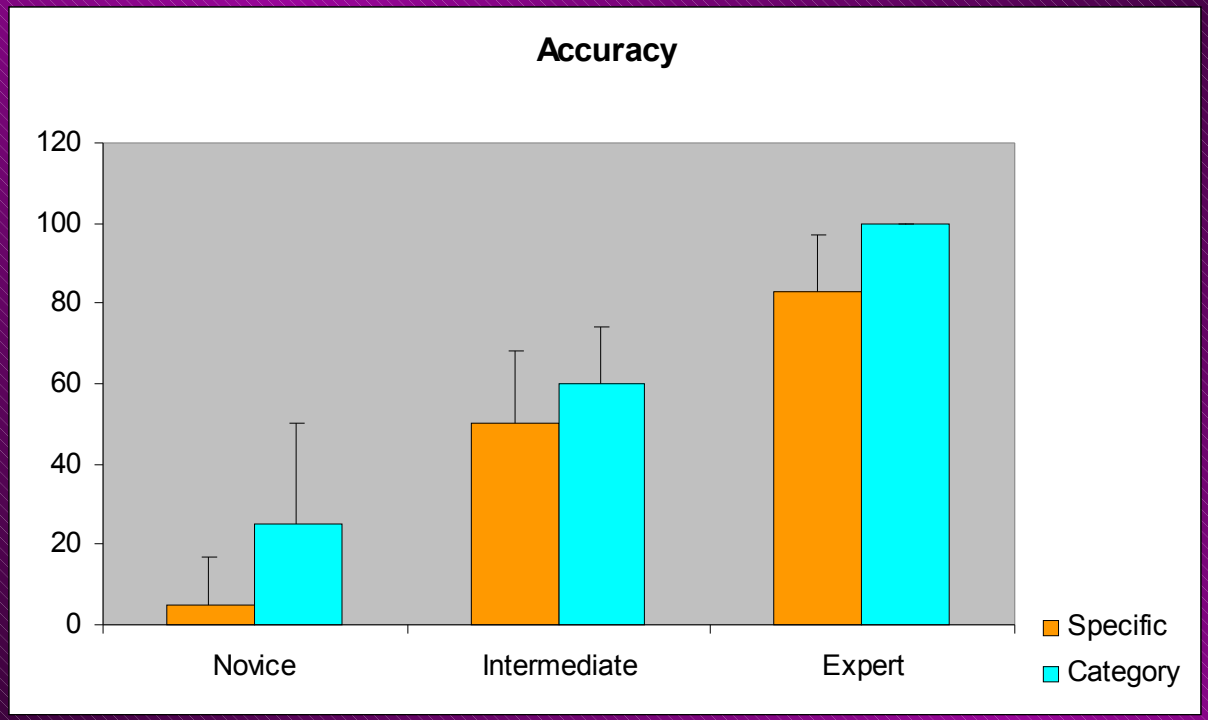
3	Okay let's look at low power		
4	I think the tissue is breast	→	*identify-anatomic-location*
5	I recognize some normal		
6	Here is in situ carcinoma	→	*statement-of-hypothesis*
7	I have to find out if there is any invasion	→	*set-goal-identify*

An example protocol: An intermediate diagnosing DCIS

Intermediate I5:

20	and some of the ducts that are expanded with small cells	→ *identify-histologic-cue*
4	with focal, possibly central, area of necrosis.	→ *identify-histologic-cue*
5	So just scan this slide around and try to determine some focal areas that I want to concentrate and focus on.	
6	Now I'm looking at some of the ducts that are expanded.	
25	And some of these ducts, they also have holes,	→ *identify-histologic-cue*
26	and these are sort of punched-out holes,	→ *identify-histologic-cue*
27	very uniform, which…	→ *identify-histologic-cue*
29	So at this magnification, I think it is a DCIS.	→ *statement-of-hypothesis*

Overall accuracy



Aggregated Process Differences

Measure	Novice		Intermediate		Expert		ANOVA			
	Mean	SD	Mean	SD	Mean	SD	F Value	P Value	Pairwise Comparison (Tukey HSD)	P Value
Data examination										
Identification	14.1	5.4	20.5	8.2	8.0	2.8	9.4	.001	N, I	.065
									N, E	.110
									E, I	.001
Comparison	2.2	1.2	3.3	1.5	0.93	0.66	8.7	.001	N, I	.132
									N, E	.077
									E, I	.001
History	1.4	0.5	1.7	0.7	1.2	0.8	1.7	.210	N, I	.511
									N, E	.741
									E, I	.191
Data exploration and explanation	2.6	1.6	4.5	2.4	2.0	1.6	4.4	.023	N, I	.081
									N, E	.794
									E, I	.027
Data interpretation	4.9	1.6	11.4	4.1	8.4	3.6	9.8	.001	N, I	.000
									N, E	.084
									E, I	.153
Operational processes	2.6	2.1	4.4	1.8	1.5	1.6	5.4	.011	N, I	.119
									N, E	.408
									E, I	.009
Goal-setting	0.4	0.4	1.7	1.3	1.8	2.0	3.3	.052	N, I	.094
									N, E	.083
									E, I	.981
Unique hypotheses	2.2	0.6	4.0	0.9	3.3	1.2	11.3	<.001	N, I	<.001
									N, E	.031
									E, I	.210

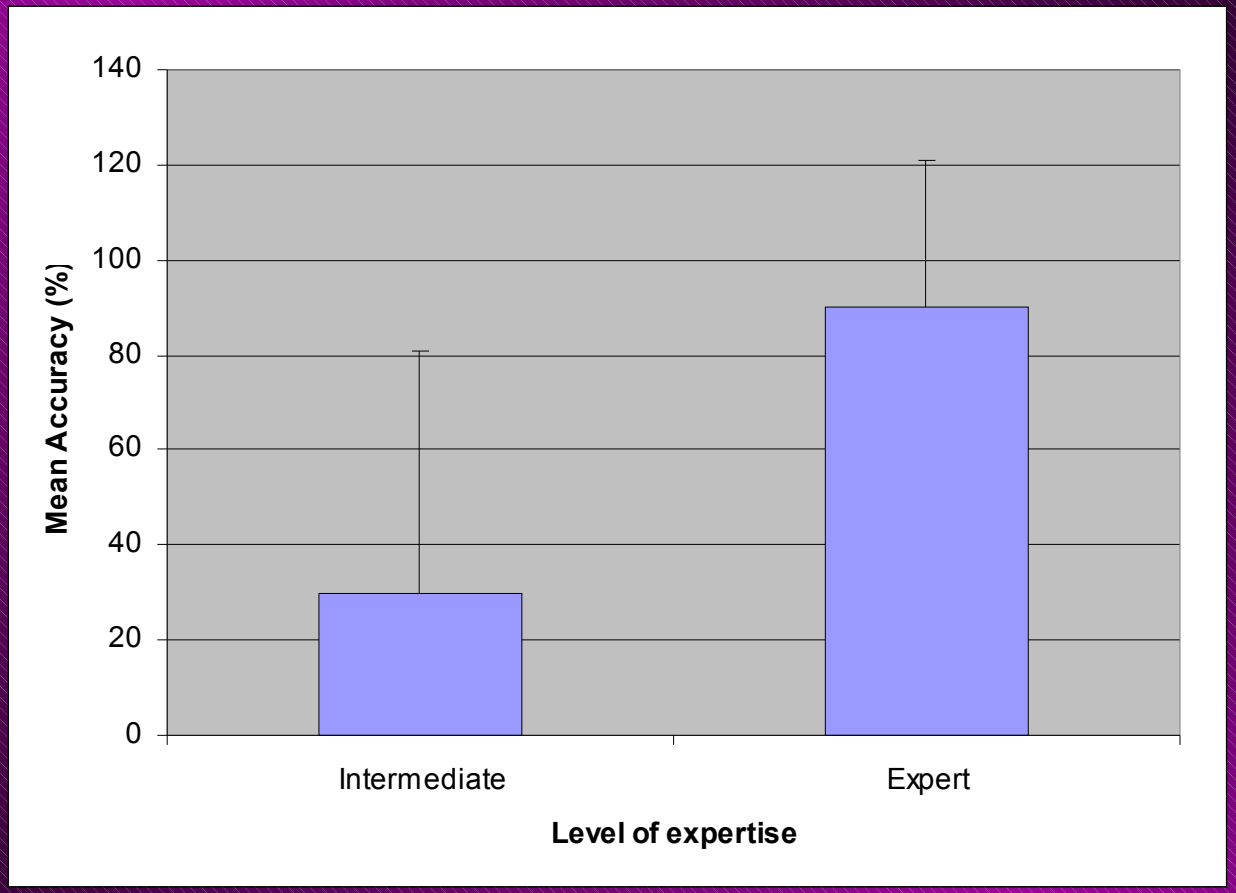
Crowley, Naus, Stewart & Friedman, in press

Task Errors

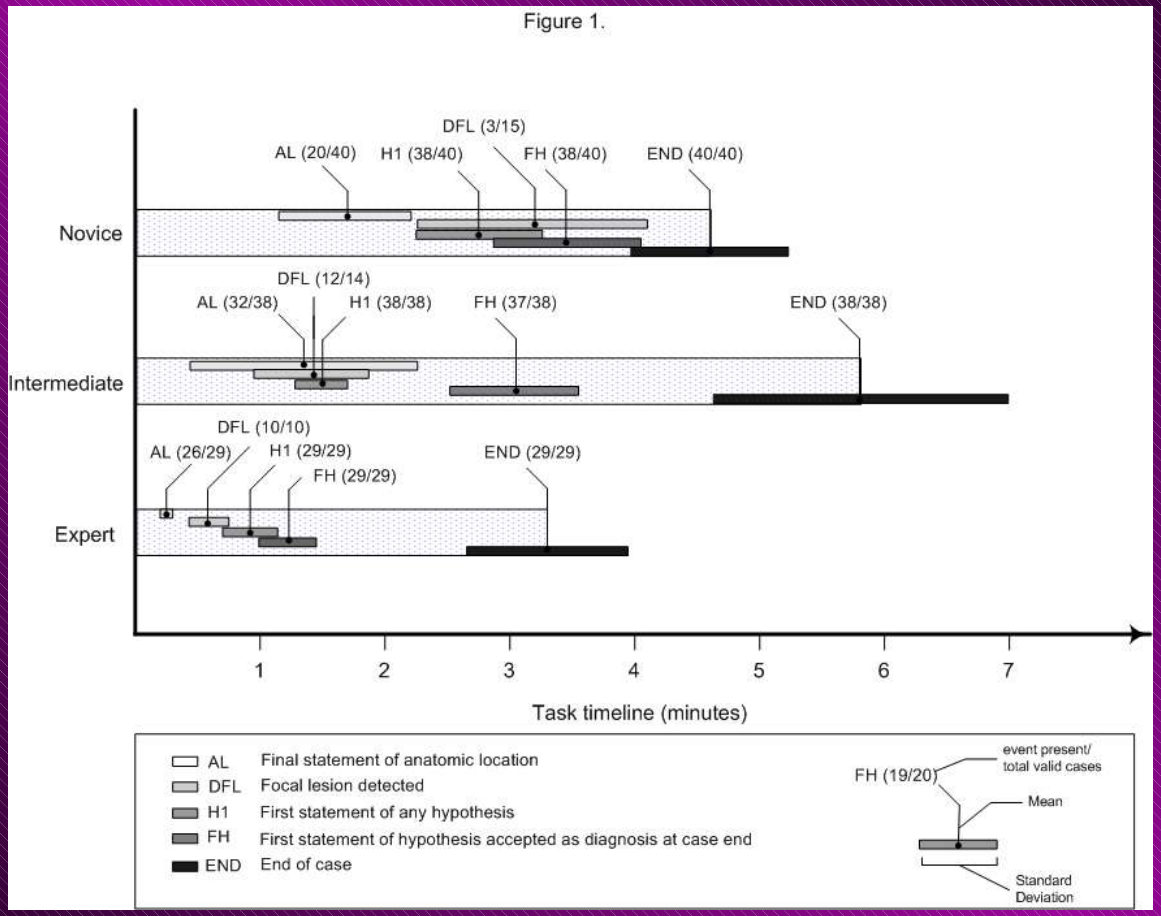
Errors	Description	Novice	Intermediate	Expert	Statistics			
Case Level	**Errors coded as present or absent in each case**	**Number of cases / Total (%)**	**Number of cases / Total (%)**	**Number of cases / Total (%)**	**Chi-Square**	**P Value**	**Pairwise Comparison**	**P Value**
1	Lesion never brought under objective	8/30 (26.7 %)	1/28 (3.6 %)	0/23 (0 %)	13.25	.0021	N, I N, E E, I	.0059 .0006 .3189
2	Lesion traversed without recognition	7/30 (23.3 %)	0/28 (0 %)	0/23 (0 %)	8.11	.0209	N, I N, E E, I	.0056 .0058 -
3	Error in identifying anatomic location	14/40 (35.0 %)	2/38 (5.3 %)	0/32 (0 %)	22.76	<.0001	N, I N, E E, I	.0008 <.0001 .1612
Segment Level	**Errors counted for each case**	**Mean/ case** **SD**	**Mean/ case** **SD**	**Mean/ case** **SD**	**F Value**	**P Value**	**Pairwise Comparison (TukeyHSD)**	**P Value**
4	Incorrectly names normal structure	0.35 0.74	0.11 0.31	0 0	5.28	.012	N, I N, E E, I	.068 .013 .656
5	Incorrectly names histopathologic cue	0.93 1.4	0.76 1.08	.003 .18	7.05	.004	N, I N, E E, I	.669 .024 .004
6	Error in assigning significance,	0.48 0.82	0.32 0.57	.003 .18	3.17	.059	N, I N, E E, I	.552 .048 .298

Crowley, Naus, Stewart & Friedman, in press

Intermediates detect but cannot accurately classify



Task Analysis Latencies



Crowley, Naus, Stewart & Friedman, in press

Lessons learned

This is a multi-step process requiring three different sets of skills and several minutes.	Model these processes using a model-tracing approach.
Searching the slide is a difficult first step.	Connect the model to a virtual microscope; Include rules for searching and magnification use.
Uncertainty and error in identification of visual features	Require the student to explicitly relate image features to diagnostic criteria. Give feedback.
Rapid pattern matching is preceded by explicit inference.	Make these explicit reasoning steps visible to the student, require that they argue for and support their diagnosis in a graphical reasoning interface.

Two systems that incorporate virtual slides

	SlideTutor	Virtual Slide Set
Design Paradigm	Intelligent Tutoring System	Computer-Assisted Instruction
Domain	Dermatopathology	Domain-Neutral
Audience	Residents/Fellows	Medical Students
Development Strategy	Long term Research Project	Iterative Development/ Deployment Cycle
Web Access	Client/Server Application downloaded and updated with Java WebStart	Use from any Java enabled browser (currently Windows only)
Knowledge Base	Yes	No
Authoring Priveleges	Controlled	Open
Authoring Requirements	Minimal	Maximal
Individualization	Maximal	Minimal

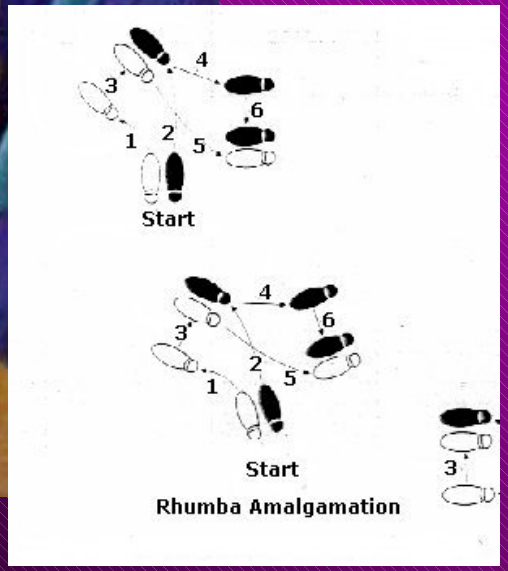
Design and development of an Intelligent Tutoring System in Pathology

Intelligent Tutoring Systems

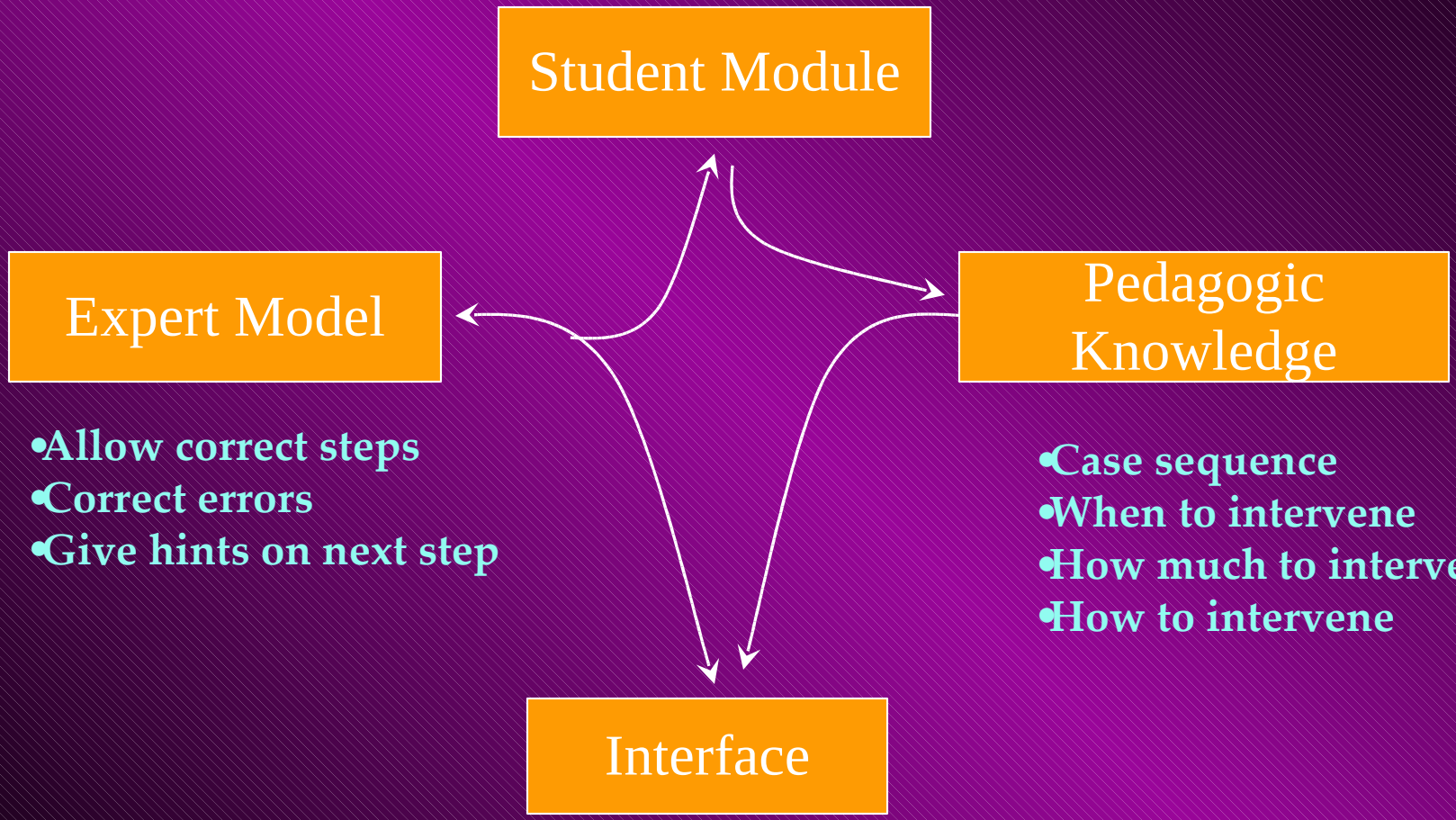
- Systems that use AI formalisms to offer interactive computer-based instruction
- “Learning by doing” +
- Represent knowledge
- Actively encode student’s progress
- Offer content based on systems model of student
- Offer instruction and hints based on systems model of student
- Provide feedback about how the student is learning
- Adaptive, flexible, *individually tailored* instruction

Alot like a Ballroom Dance Lesson

- Learning by Doing
- Student leads
- Right step?…teacher follows
- Wrong Step?…teacher corrects
- Lost?…teacher leads but only for a moment
- Production Rule Systems and Probabilistic Models



- Collect data on what student does
- Make predictions on what student knows
- Provide data for pedagogic decision making



- Allow correct steps
- Correct errors
- Give hints on next step

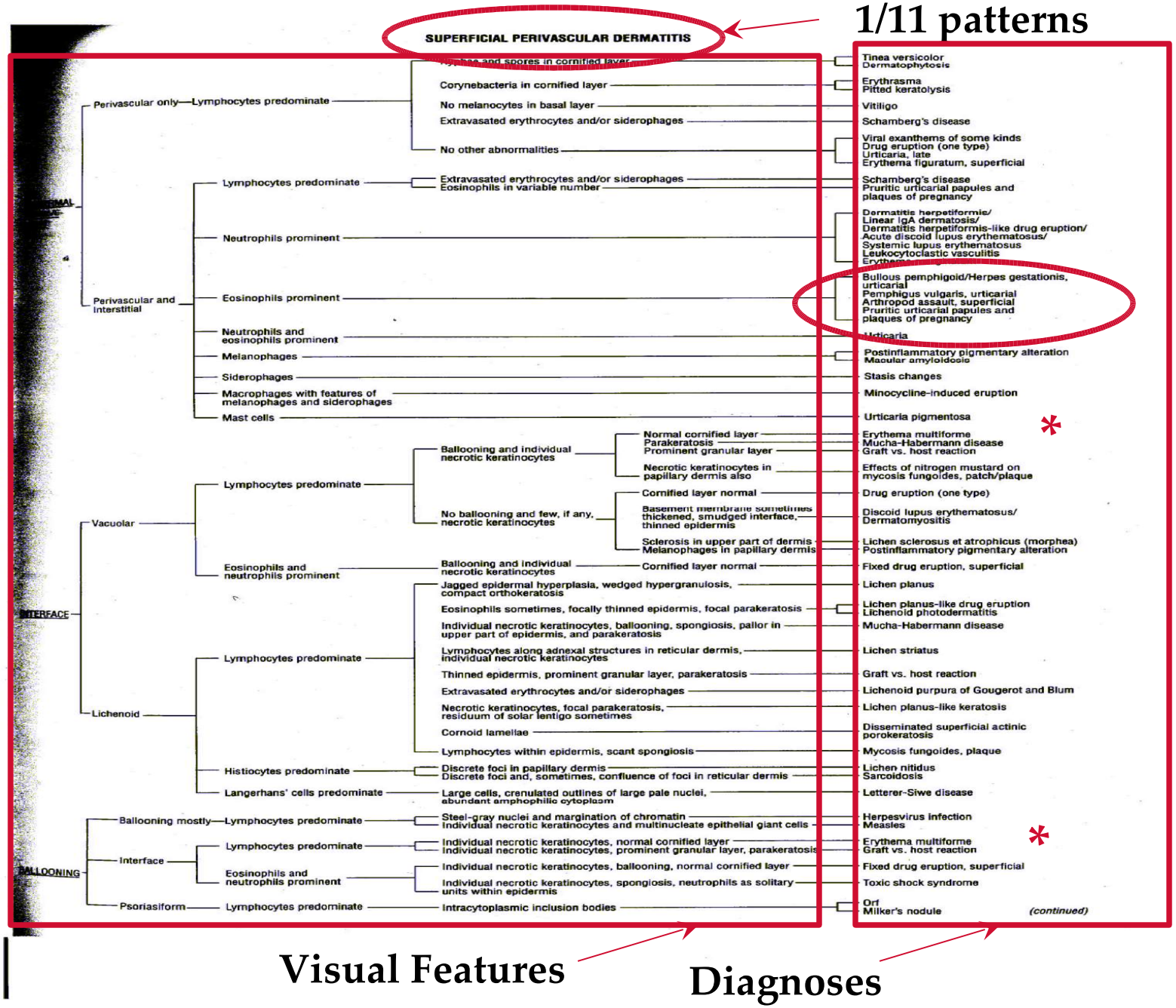
- Case sequence
- When to intervene
- How much to intervene
- How to intervene

- Canvas for problem solving
- Make goals visible
- Provide metaphors and novel notations

Dermatopathology as a Domain for an ITS

- Extremely difficult
- Residents have little time to learn
- False positives and false negatives; errors associated with significant impact to patient
- Some areas are highly algorithmic, seemed straightforward to model with rule system
- Some areas not so straightforward to model with rule system

1/11 patterns



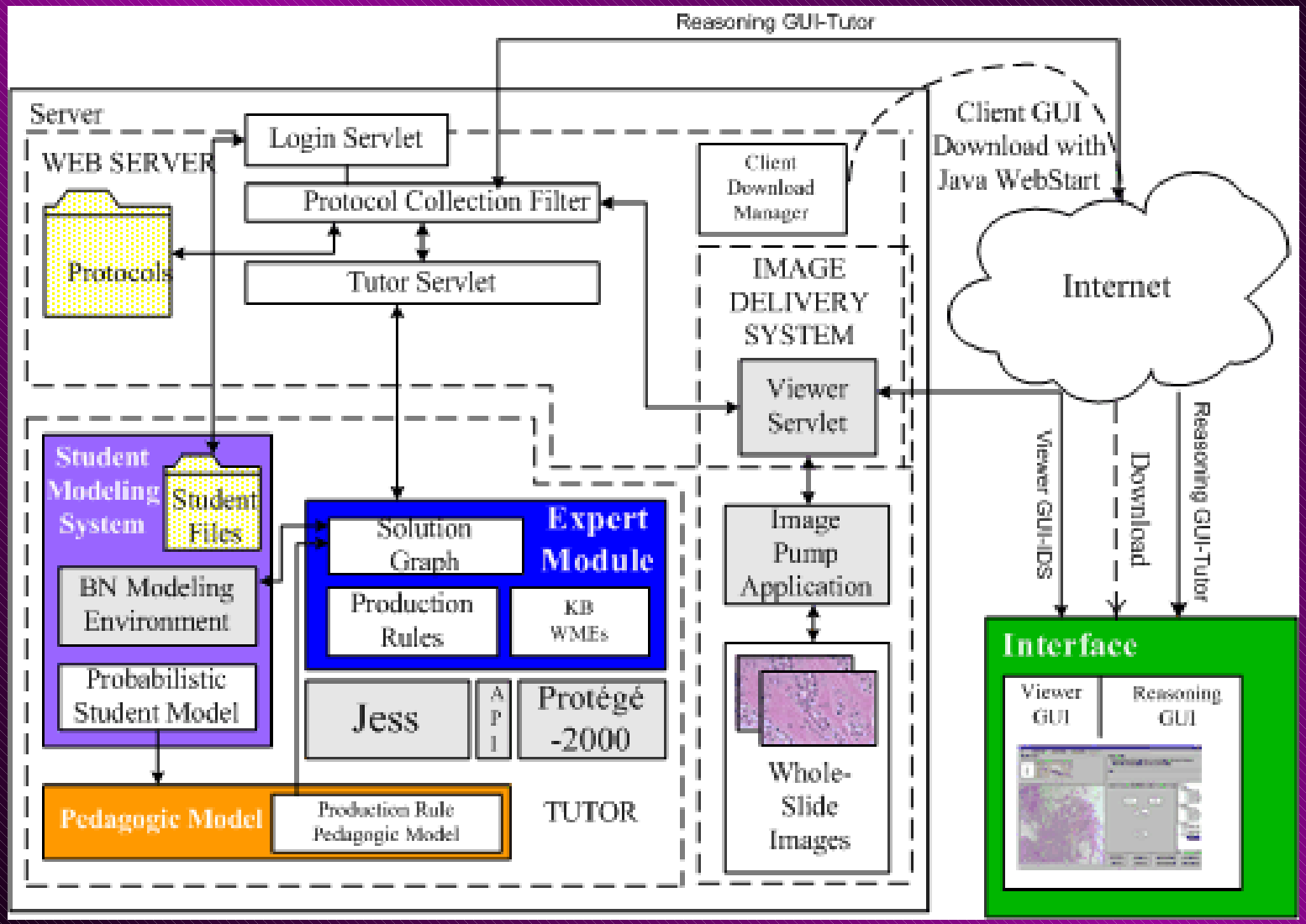
Visual Features

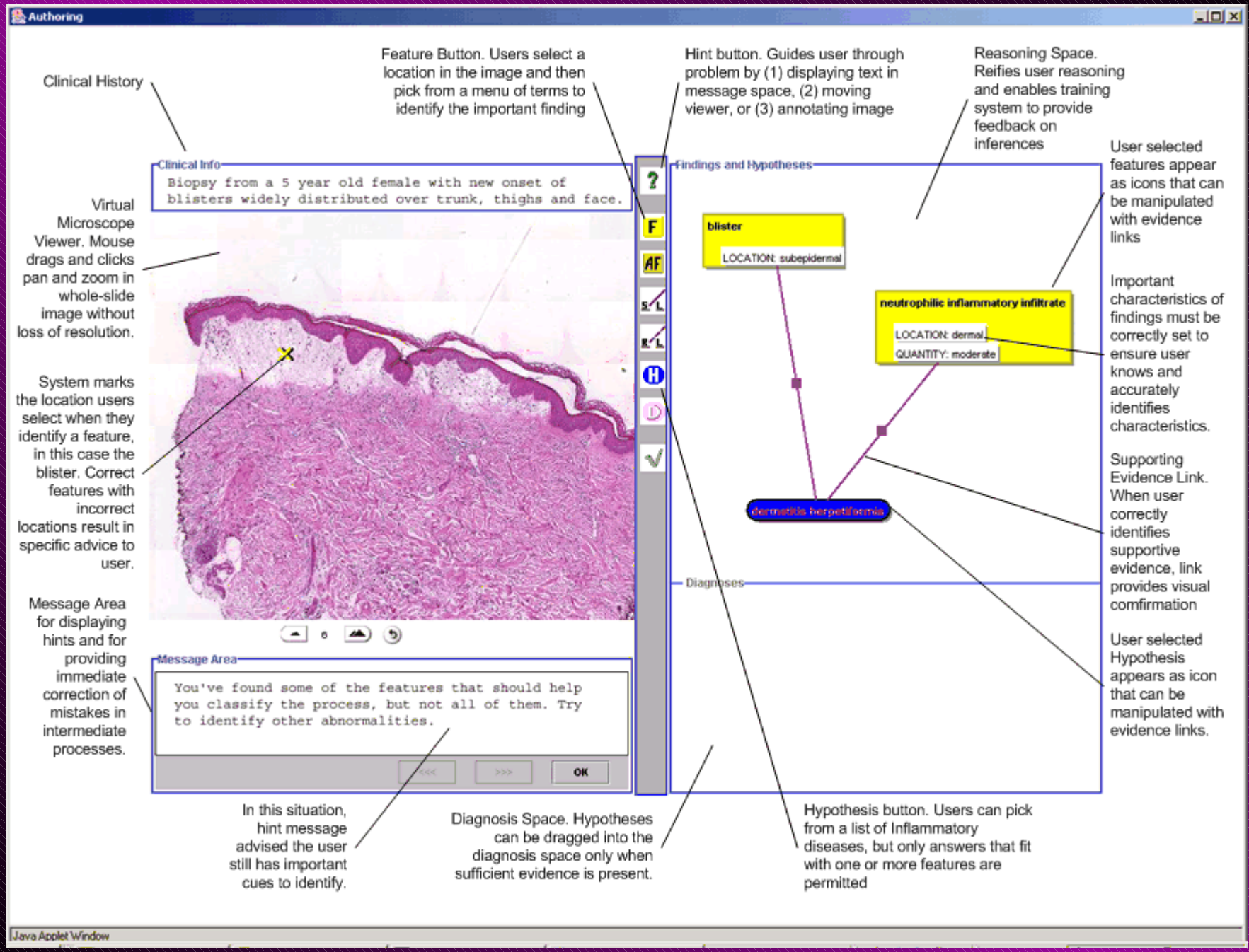
Diagnoses

Tools and Standards

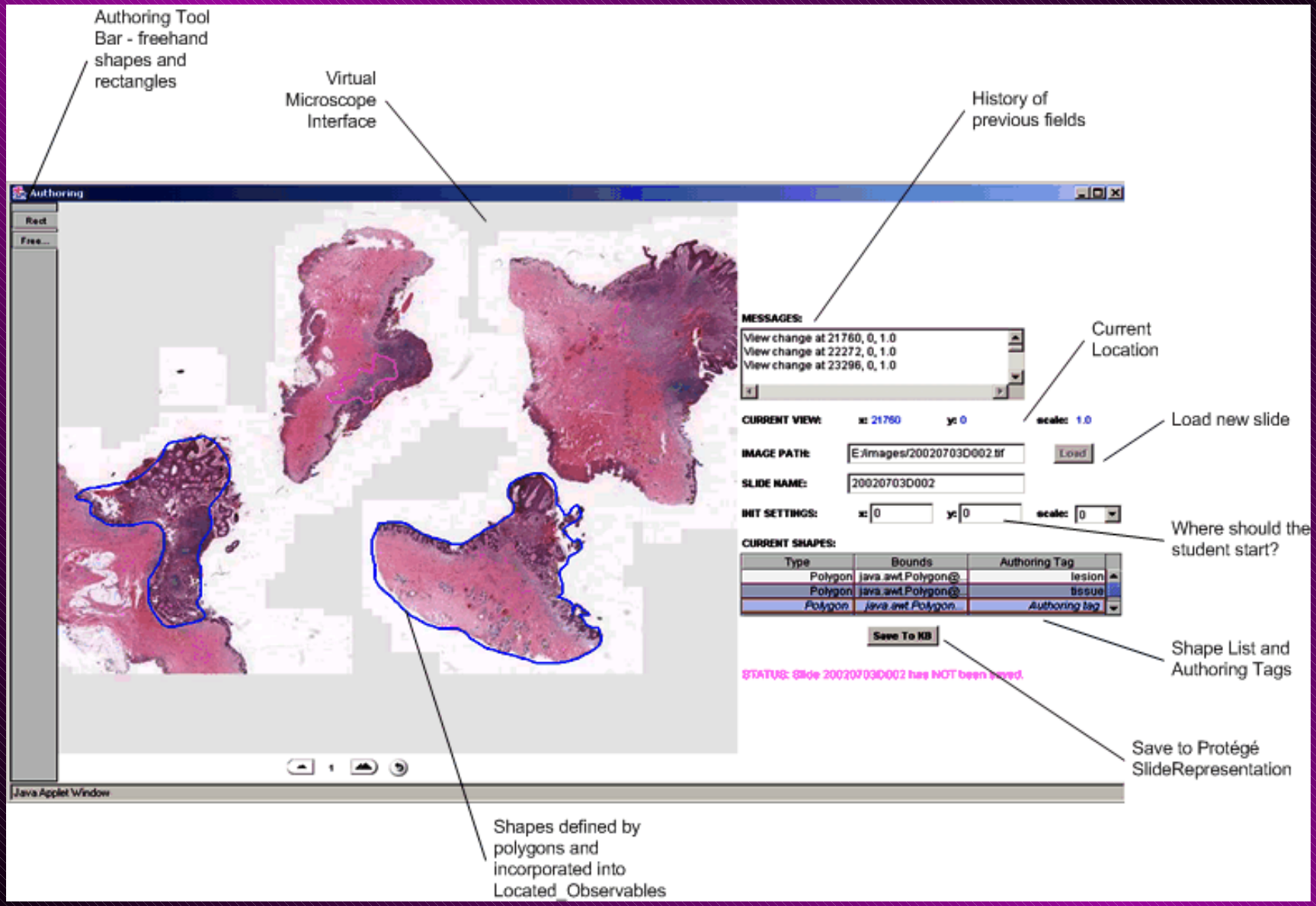
- Web-deployed using Java WebStart
  http://java.sun.com/products/javawebstart/
- Jess – Java Production Rule System, abstract PSMs
  http://herzberg.ca.sandia.gov/jess/
- Protégé-2000 Ontology/WME editor
  http://protege.stanford.edu/index.html
- IBROW Standards Classification Problem Solving
  http://www.swi.psy.uva.nl/projects/IBROW3/home.html
- FIPA Agent Standards
  http://www.fipa.org/specs/fipa00001/XC00001J.html#_Toc8186403
- Xippix ImagePump Software
  http://www.xippix.com/index.html

Tutor Architecture




Authoring
Clinical History
Feature Button. Users select a location in the image and then pick from a menu of terms to identify the important finding
Hint button. Guides user through problem by (1) displaying text in message space, (2) moving viewer, or (3) annotating image
Reasoning Space. Reifies user reasoning and enables training system to provide feedback on inferences
Clinical Info
Biopsy from a 5 year old female with new onset of blisters widely distributed over trunk, thighs and face.
Findings and Hypotheses
blister
LOCATION: subepidermal
neutrophilic inflammatory infiltrate
LOCATION: dermal
QUANTITY: moderate
dermatitis herpetiformis
Diagnoses
F
AF
S.L.
R.L.
H
D
Virtual Microscope Viewer. Mouse drags and clicks pan and zoom in whole-slide image without loss of resolution.
System marks the location users select when they identify a feature, in this case the blister. Correct features with incorrect locations result in specific advice to user.
Message Area for displaying hints and for providing immediate correction of mistakes in intermediate processes.
Message Area
You've found some of the features that should help you classify the process, but not all of them. Try to identify other abnormalities.
<<<
>>>
OK
User selected features appear as icons that can be manipulated with evidence links
Important characteristics of findings must be correctly set to ensure user knows and accurately identifies characteristics.
Supporting Evidence Link. When user correctly identifies supportive evidence, link provides visual comfirmation
User selected Hypothesis appears as icon that can be manipulated with evidence links.
In this situation, hint message advised the user still has important cues to identify.
Diagnosis Space. Hypotheses can be dragged into the diagnosis space only when sufficient evidence is present.
Hypothesis button. Users can pick from a list of Inflammatory diseases, but only answers that fit with one or more features are permitted
Java Applet Window

Current Slide Authoring Tool



Demonstration

- **Protégé-2000 Knowledge Base**
- Slide Tutor Student Interface
- Slide Tutor Authoring Tool

Future Questions

- Is immediate feedback a good thing? Or should we let students make mistakes?
- What are the tradeoffs among expressiveness, validity, predictive value, and run-time speed of various student modeling options?
- What kinds of interventions help students learn faster?
- What kinds of interface metaphors and mechanisms foster a deep understanding of the process?
- Should we teach Pathology breadth-first, or depth-first?
- Do different students need different feedback?

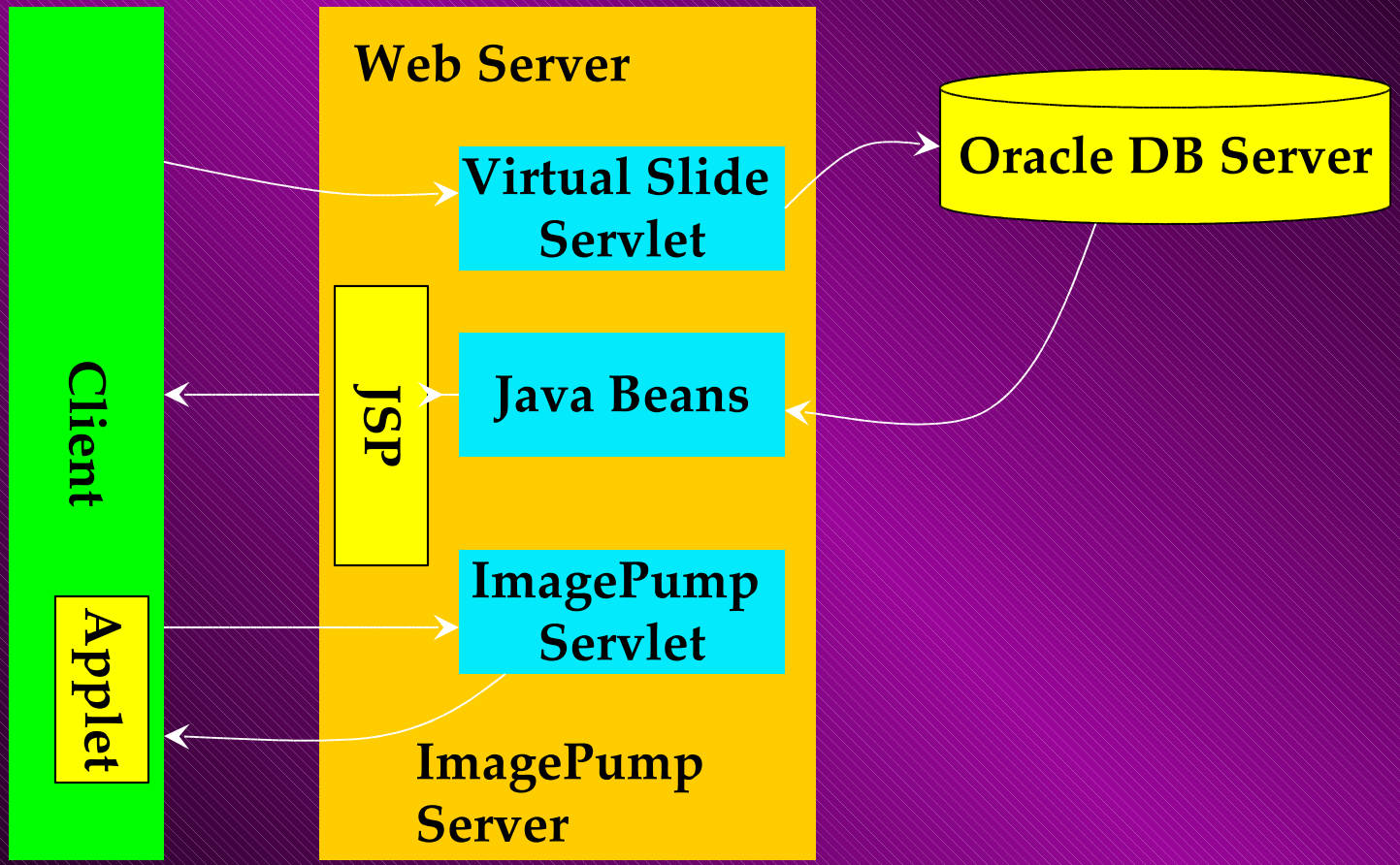
Virtual Slide Set - Research Goals

- Develop a web-based system for authoring and presenting virtual slides in case based context
- Support Medical School Courses that include a Pathology Component
- Create methods for individualization, personal preferences and different views of the data
- Integrate our system with existing Online educational system at University of Pittsburgh to give students a single gateway
- Iterative design, development and deployment across multiple courses
- Evaluate using traditional survey, observation, and log-file methods

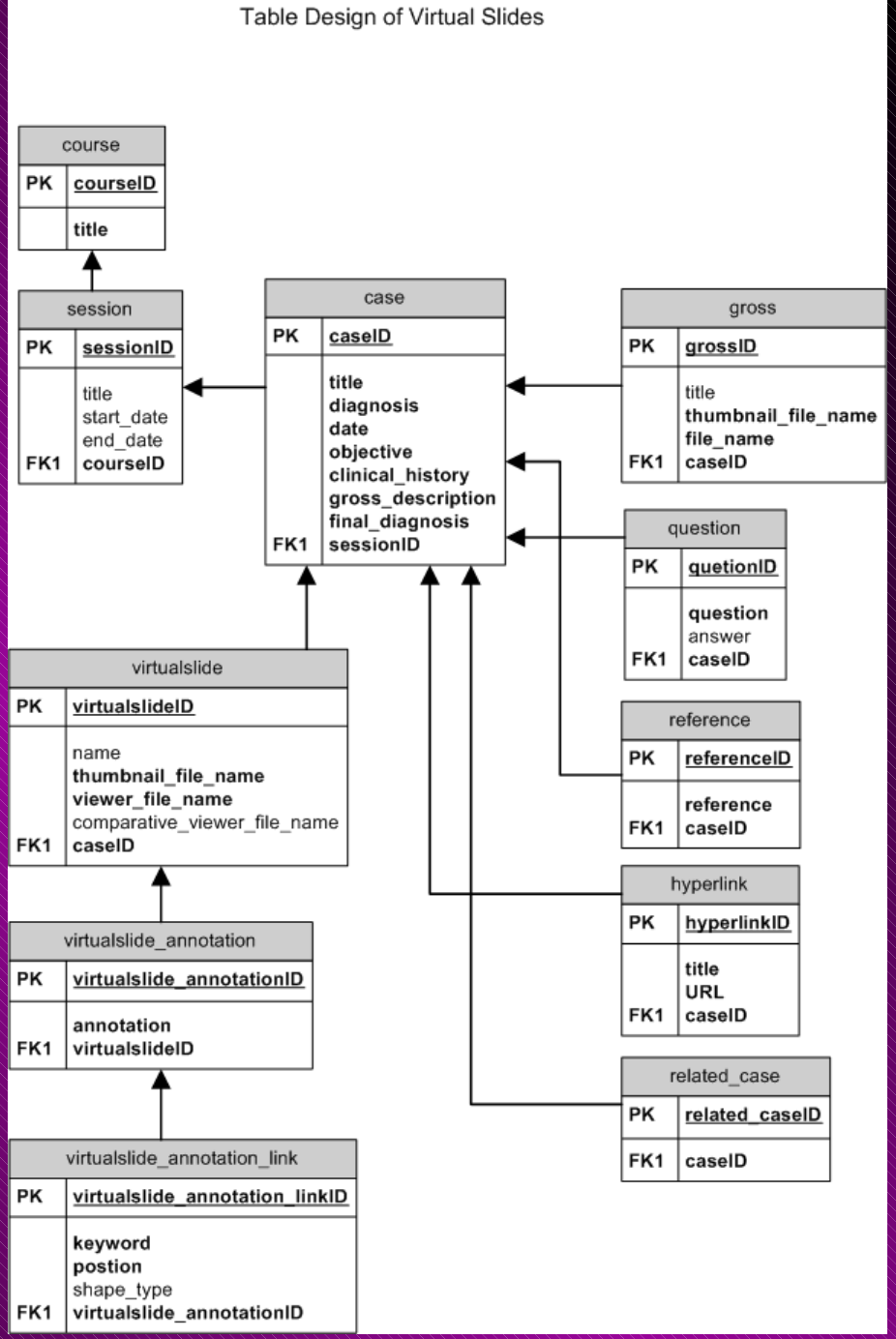
Virtual Slide Set - Approach

- Case-based learning
- WWW – JVM - no other special needs
- Empty vessel for communication
- Use-neutral; applicable to many different educational settings
- Teach microscopic skills but in a clinical context
- Rich text – image annotation

Virtual Slide Set – System Design



Relational Design



Virtual Slide Set – Demonstration

- **Virtual Slide Set**

Virtual Slide Set - Progress

- Host Defenses Course, 2002
  - Prototype system
  - Single Laboratory Session on Neoplasia
  - 72 MS-I students working in pairs on five cases
  - 74 MS-I students with microscopes seeing same five cases
  - Response universally enthusiastic
- GI Course, 2002
  - Presentation layer deployed
  - Cirrhosis Self Study Module
  - All students responsible for working through material on their own
- Neuroscience Course, February 2003
  - First expected use of authoring system with NS instructors
  - First expected use of Discover, Guide and Annotate preferences

Virtual Slide Set - Response

- Evaluation limited to a single course
- No significant differences between groups for confidence with identifying features, percieved effect on identifying questions or solidifying concepts in lecture
- Significant difference in students' predictions about reviewing cases as Vslides as opposed to traditional slides
- Many interesting and useful comments
  - "I didn't have to waste my time focusing"
  - "Awesome. I can do it alone and when I feel like it"
  - "Annoying to use – would rather use a microscope. Difficult to watch screen and wait for image to adjust"
  - "Reviewing the material in a clinical case put the info in context"
- More complete evaluation planned using log file analyses, surveys and observation

Future Questions

- How do we integrate Virtual Slides into developing on-line educational resources?
- What do we need to do to get instructors with no expertise in IT or informatics to contribute their instructional content, create annotated slides, etc. ?
- How do we make Vslide sites so that they can be individualized and used for multiple purposes, and in multiple context?s.

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