Evolving and Packaging Reading Techniques Through Experimentation

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Evolving Knowledge
Model Building, Experimenting, and Learning

Understanding a discipline involves building models,
e.g., application domain, problem solving processes

Checking our understanding is correct involves

- testing our models
- experimentation

Analyzing the results of the experiment involves learning, the encapsulation of knowledge and the ability to change and refine our models over time

The understanding of a discipline evolves over time

Knowledge encapsulation allows us to deal with higher levels of abstraction

This is the paradigm that has been used in many fields,
e.g., physics, medicine, manufacturing.

Evolving Knowledge
Model Building, Experimenting, and Learning

What do these fields have in common?

They evolved as disciplines when they began applying the cycle of model building, experimenting, and learning

Began with observation and the recording of what was observed

Evolved to manipulating the variables and studying the effects of change in the variables

What are the differences of these fields?

The objects they study, the properties of those object, the properties of the system that contain them, the relationship of the object to the system, and the culture of the discipline

This effects

how models are built and analyzed
how experimentation gets done

Evolving Knowledge
Model Building, Experimenting, and Learning

Like other disciplines, software engineering requires the cycle of model building, experimentation, and learning

The study of software engineering is a laboratory science

We need to understand the nature of the processes, products and the relationship between the two in the context of the system

Research and Development have a symbiotic relationship

Research needs laboratories to observe & manipulate the variables
- they only exist where developers build software systems

Development needs to understand how to build systems better
- research can provide models to help

The Experimental Discipline

Classes of Experimental Studies

Experiment Classes

		#Projects	
		One	More than one
# of Teams per Project	One	Single Project	Multi-Project Variation
	More than one	Replicated Project	Blocked Subject-Project

The Experimental Discipline

Sign of maturity in a field:

level of sophistication of the goals of an experiment

understanding interesting things about the discipline

For software engineering that might mean:

Can we build models that allow use to measure and differentiate processes and products?

Can we measure the effect of a change in a particular process variable on the product variable?

Can we predict the characteristics of a product (values of product variable) based upon the model of the process (values of the process variables), within a particular context?

Can we control for product effects, based upon goals, given a particular set of context variables?

The Experimental Discipline

Sign of maturity in a field:
a **pattern of knowledge** built from a **series of experiments**

Does the discipline build on prior (knowledge, models, experiments).

Was the study an isolated event?

Did it lead to other studies that made use of the information obtained from it

Have studies been replicated under similar or differing conditions?

Does the building of knowledge exist in one research group or environment, or has it spread to others - researchers building on each other's experimental work?

For example, inspections, in general, are well studied experimentally

However, there has been very little combining of results, replication, analysis of the differentiating variables

Reading Techniques

Reading is a key technical activity for analyzing and constructing software artifacts

Reading is a model for writing

Reading is critical for reviews, maintenance, reuse, ...

What is a reading technique?

a concrete set of instructions given to the reader saying how to read and what to look for in a software product

More Specifically, software reading is

the individual analysis of a software artifact

e.g., requirements, design, code, test plans

to achieve the understanding needed for a particular task

e.g., defect detection, reuse, maintenance

Reading Techniques

Early experiments (Hetzel, Meyers) showed very little difference between reading and testing

But reading was simply reading, without a technological base

We discuss a series of experiments at the University of Maryland and at NASA used to learn about, evaluate, and evolve reading techniques

This example
- shows **multiple experimental designs**
- provides a combination of **evaluation approaches**
- offers insight into the **effects of different variables** on reading

The experiments start with
the early reading vs. testing experiments
to various Cleanroom experiments
to the scenario based reading techniques currently under study

EXPERIMENTAL LEARNING MECHANISMS

Series of Studies

		# Projects: One	# Projects: More than one
# of Teams per Project	One	**3. Cleanroom (SEL Project 1)**	**4. Cleanroom (SEL Projects, 2,3,4,...)**
	More than one	**2. Cleanroom at Maryland**	**1. Reading vs. Testing** **5. Scenario reading vs. ...**

Blocked Subject Project Study

Testing/Reading Strategies Comparison

Code Reading vs **Functional Testing** vs **Structural Testing**

Study: fault detection effectiveness, cost, classes of faults detected

Experimental design: Fractional factorial design at NASA/CSC

Some Results

Code reading (by stepwise abstraction) more
- **effective** than functional testing (equivalence partitioning)
- **efficient** than functional or structural testing (100%stmt coverage)

Different techniques more effective **for different defect classes**

Developers don't believe reading is better, not motivated to read

Blocked Subject Project Study

Testing/Reading Strategies Comparison

Fractional Factorial Design

		Code Reading			Functional Testing			Structural Testing		
		P1	P2	P3	P1	P2	P3	P1	P2	P3
Advanced Subjects	S1			X		X		X		
	S2		X		X					X
	:									
	S8	X					X		X	
Intermediate Subjects	S9			X		X		X		
	S10		X		X					X
	:									
	S19	X					X		X	
Junior Subjects	S20			X		X		X		
	S21		X		X					X
	:									
	S32	X					X		X	

Blocking by experience level and program tested

Replicated Project Study

Cleanroom Study

Cleanroom process vs. **non-Cleanroom process**

Study: effects on the process, product, developers

Experimental design: 15 three-person teams at UMD

Some Results

Cleanroom developers were motivated to read better

Reading by step-wise abstraction more effective and efficient

Does Cleanroom scale up? Will it work on a real project?

Single Project Study

Cleanroom in the SEL

Cleanroom process vs. **Standard SEL Approach**

Study: effects on the effort distribution, cost, and reliability

Experimental design: Flight Dynamics project in the SEL

Some Results

Reading by step-wise abstraction effective and efficient
Reading appears to reduce the cost of change

Better training needed for reading by stepwise abstraction

Will it work again? Can we scale up more?

Multi-Project Analysis Study

Cleanroom in the SEL

Revised Cleanroom process vs. **Standard SEL Approach**

Study: effects on the effort distribution, cost, and reliability

Experimental design: Three Flight Dynamics projects in the SEL

Some Results

Reading by step-wise abstraction
- effective and efficient in the SEL
- appears to reduce the cost of change

Better training needed for reading by stepwise abstraction

Better reading techniques needed for other documents, e.g., requirements, design, test plan

Can we improve the reading techniques for requirements and design documents?

Scenario-Based Reading Definition

An approach to generating a family of reading techniques, called operational scenarios, has been defined to be
- procedurally defined
- document and notation specific
- goal driven
- tailorable to the project and environment
- focused to provide a particular coverage of the document
- empirically verified to be effective for its use
- usable in existing methods, such as inspections

So far, four techniques have been defined and studied :

perspective based reading: for requirements documents

defect based reading: for requirements documents

scope based reading: for design reuse

use based reading: for user interface design

All techniques have been applied in a series of experiments

Scenario-Based Reading Definition

- Need to characterize the "model of use": how the information in a document is used for a particular task in a particular environment.

Abstractions of Information:
A model of what information is important, and how it is best organized

Uses of Information:
A model of the process by which the task is accomplished

Initial procedures for identifying information in this document that is relevant

Initial procedures for using the information to accomplish the task

Reading Technique:
Tested practices for accomplishing a particular task

Reading for Analysis: Scenario-Based Reading Definition

So far, two different scenario-based reading techniques have been defined for requirements documents:

defect based reading

perspective based reading

Defect based reading focuses on different defect classes

e.g., missing functionality and data type inconsistencies

Existing definition for reading SCR style documents

Perspective-based reading focuses on different customer perspectives, e.g., reading from the perspective of the designer, tester, or end-user

Existing definition for reading natural language requirements documents.

Perspective-Based Reading

Abstractions of Information:
Design plan
Test plan
User manual

Uses of Information:
Check consistency
Check completeness
Check correctness . . .

Allow reviewers to use their usual procedures

Create questions aimed at checking each attribute

Reading Technique:
For detecting defects in requirements

Ask reviewers to create the appropriate abstraction, then answer a series of questions tailored to the abstraction

Reading for Analysis: Blocked Subject Project Study

Perspective-Based Reading

Study Goal:

Analyze perspective-based reading, NASA's current reading technique to evaluate and compare them with respect to their effect on fault detection effectiveness in the context of an inspection team from the viewpoint of quality assurance

Environment:

NASA/CSC SEL Environment
Requirements documents:
Two NASA Functional Specifications: ground support subsystems
Two Structured Text Documents: ATM machine, Parking Garage
All documents seeded with known defects

Experimental design:

Metric: Percent of defects detected
Blocked subject-project: Partial factorial design
Replicated twice: November 1994 and June 1995
Subjects: 25 subjects in total

Reading for Analysis: Perspective-Based Reading Experiment

Major Results

PBR most successful in the generic domain
- both at the individual and team level
- caught more defects
- caught different defects depending on the perspective

PBR not sufficiently tailored to the NASA environment in terms of document contents, notation and perspectives

PBR successful at the team level for only one of the NASA documents
- caught more defects
- did not catch significantly different defects

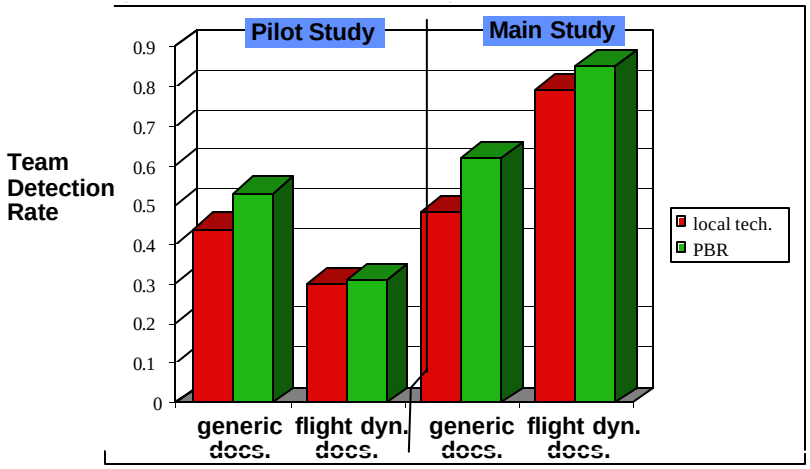
The relative benefit of PBR is higher for teams

Potential Improvements
- Be more specific to avoid subjects falling back to familiar technique
- Tailor PBR to the domain to achieve full potential

Reading for Analysis: Perspective-Based Reading Experiment

Goal of Perspective-Based Reading (PBR):
detect defects in a requirements document
focus on product consumers

Controlled experiment run twice with NASA professionals:



Reading for Analysis: Blocked Subject-Project Study

Defect-Based Reading

Study Goal:

Analyze defect-based reading, ad-hoc reading and check-list based reading to evaluate and compare them

with respect to their effect on fault detection effectiveness in the context of an inspection team

from the viewpoint of quality assurance

Environment:

University of Maryland graduate courses
Requirements documents written in SCR notation
Water Level Monitoring System, Cruise Control System

Experimental design:

Blocked subject-project: Partial factorial design
Replicated twice
Subjects: 48 subjects in total

Reading for Analysis: Blocked Subject Project Study

Defect-Based Reading

Major Results

Scenario readers performed better than Ad Hoc and Checklist Readers improvement of about 35%

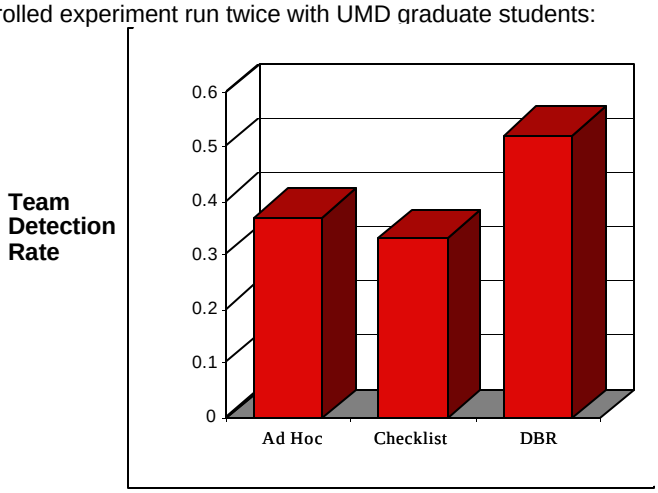
Scenarios helped reviewers focus on specific fault classes but were no less effective at detecting other faults

Checklist reading was no more effective than Ad Hoc reading

Reading for Analysis: Defect-Based Reading Experiment

Goal of Defect-Based Reading (DBR):
detect defects in a requirements document
focus on defect classes

Controlled experiment run twice with UMD graduate students:



Reading for Analysis: Use-Based Reading

Definition

Perspective-based reading for user interface analysis

Used three different perspectives:
- expert-based reading
- novice-based reading
- error-based reading

Based upon perspectives, provide a set of questions that needed to be tailored to the particular interface being inspected

This provides each reader with and inspection procedure

The reader should then find anomalies and assess the document from their particular point of view.

Reading for Analysis: Replicated Project Study

Use-Based Reading

Study Goal:

Analyze use-based reading and heuristic evaluation to evaluate and compare them with respect to their effect on anomaly detection effectiveness in the context of an inspection team from the viewpoint of quality assurance

Environments:

Bureau of Standards (24), 2 web interfaces for census data collection
HCI undergraduate/graduate class (44), studied a web site
HCI professional SE class (42), studied same web site

Experimental designs:

Dependent variable: number of detected anomalies of different types
(expert, novice, error)
Independent variables: procedure (UBR, HE)
procedure application (alone, pair)
Replicated experiment, random selection wrt dependent variables

Reading for Analysis: Use-Based Reading Experiment

Major Results

Use-based (Perspective-based) reading, compared to heuristic evaluation
did not require more inspection time
got a better or equivalent preference rating by performers
was more effective in detecting related anomalies,
overall found more anomalies
at individual level,
for paired application of the procedures, and
for simulated teams

The effectiveness was consistently shown with different subjects, interfaces, and time constraints

Paired teams performed better than individuals

High Level Reading Goals

We differentiate two goals for reading techniques:

Reading for analysis:
Given a document,
how do I assess
various qualities
and characteristics?

Assess for
product quality
defect detection
...

Useful for
quality control,
insights into development
...

Reading for construction:
Given a system,
how do I understand
how to use it as part
of my new system?

Understand
what a system does
what capabilities do and do not exist
...

Useful for
maintenance
building systems from reuse
...

Reading for Construction

White-Box Frameworks

We proposed two reading techniques for frameworks:
Given the object model of your application and the OO framework

System-wide **technique:**
- **Find the** class **in the** framework hierarchy **that best matches the functionality you are seeking**
- **Determine** how to parameterize that class **and how to implement it as part of your application**

Task-oriented **technique:**
- **Find the** example **in the** example set **that best matches the functionality you are seeking**
- **Determine** which piece of the example is relevant **and how to implement it as part of your application**

Controlled Experiment with UMD students

Reading for Construction

Some Results: White-Box Framework Experiment

The effectiveness of an example-based technique is heavily dependent on the quality and breadth of the example set provided.

Example-based techniques are well-suited to use by beginning learners.

A hierarchy-focused technique is not well-suited to use by beginners.

Teams who began their implementation using an existing example for guidance seemed more effective than those who began implementing from scratch.

Teams who were able to stay close to their original object model of the system during implementation seemed more effective.

Other work in Developing Techniques

We are studying

- other perspective-based techniques, e.g., use-case driven perspective
  - Does this perspective find defects not caught by other perspectives?
  - Do better defined PBR procedures provide better results?
- object oriented design reading techniques
  - scenarios based upon defect classes (UMD)
  - scenarios based upon perspectives (Fraunhofer IESE)

Can use-case driven reading technique be used in the context of a product line to help generate generic use cases for the product line?

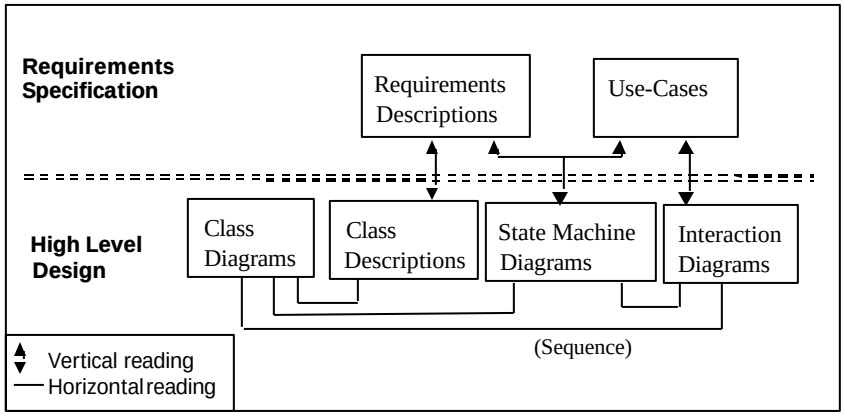
What support processes and tools are necessary?

What other families of techniques can we develop

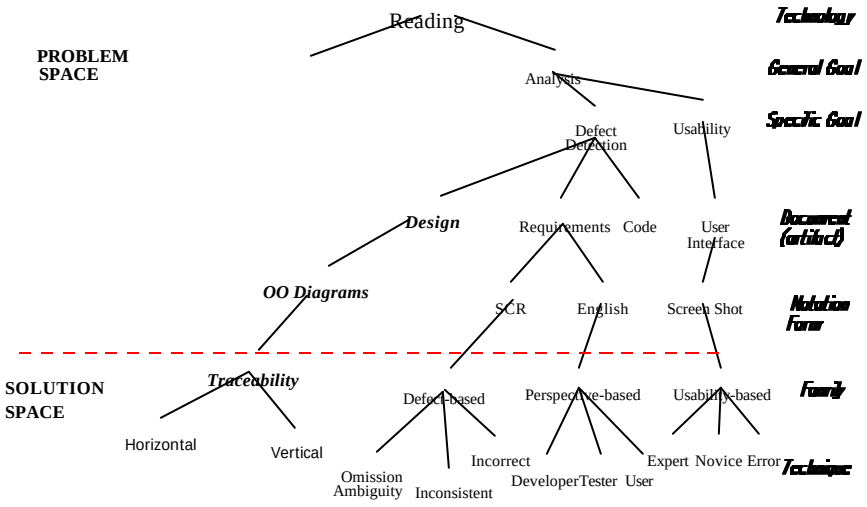
- based on empirical evaluation
- parameterized for use in different contexts

Reading Techniques for OO Design

- **Target Artifacts:**



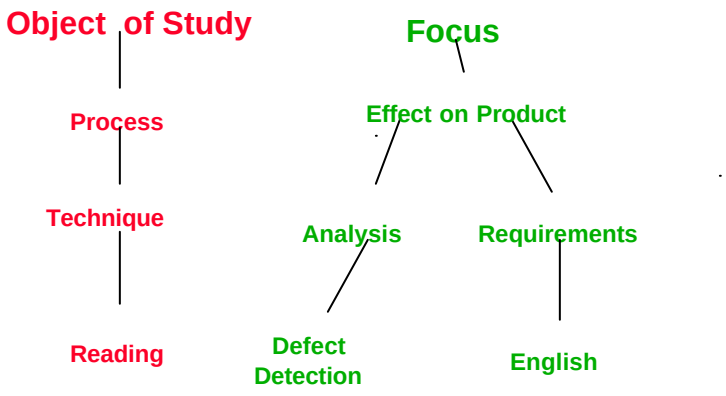
Reading Techniques for OO Design



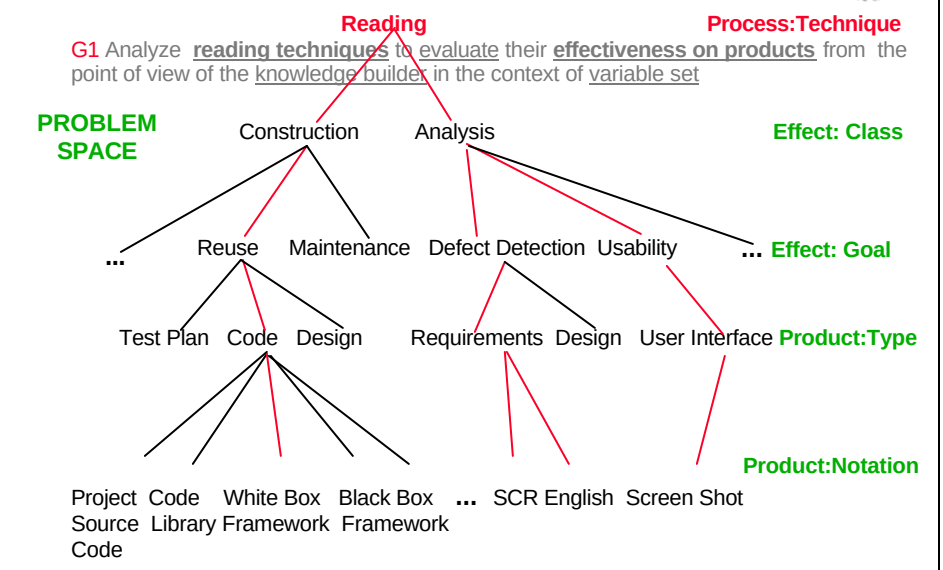
Reading Techniques for OO Design
First Experiment at UMCP

- Some results from the experiment:
  - developers agreed that using some kind of OO reading technique is worthwhile
  - some developers said that they would like to use the same techniques again but, the mechanisms used to instrument them should be improved. The study allowed us to identify weaknesses in the first version of the techniques that have led to a second version
  - It was possible to demonstrate that reading techniques can be used as part of design inspections, and do help reviewers detect defects

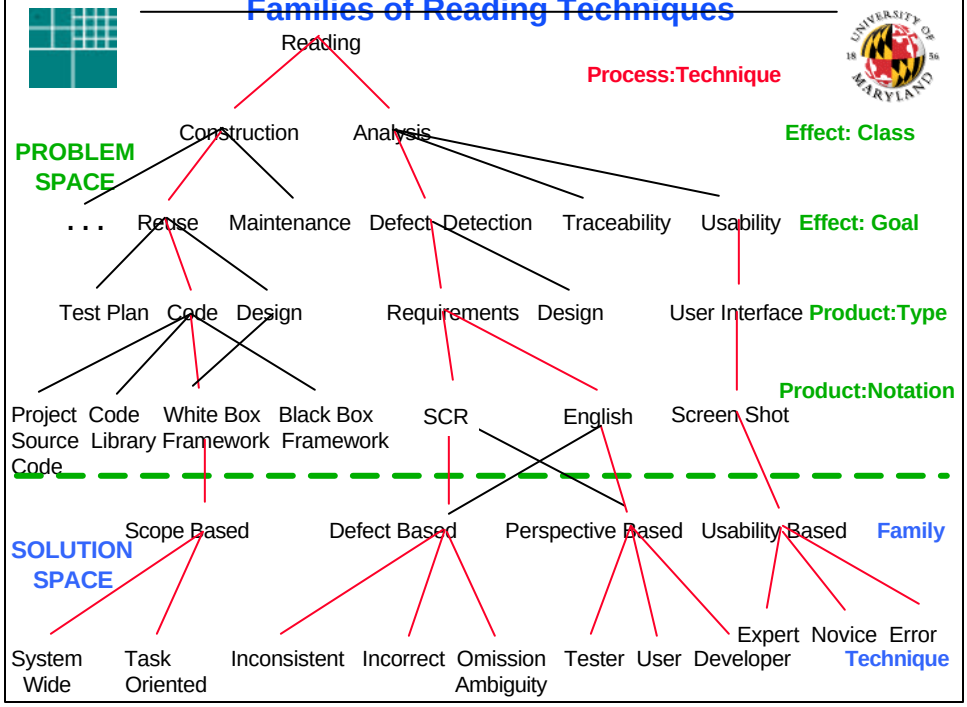
Refining a High Level Focus



Families of Reading Techniques

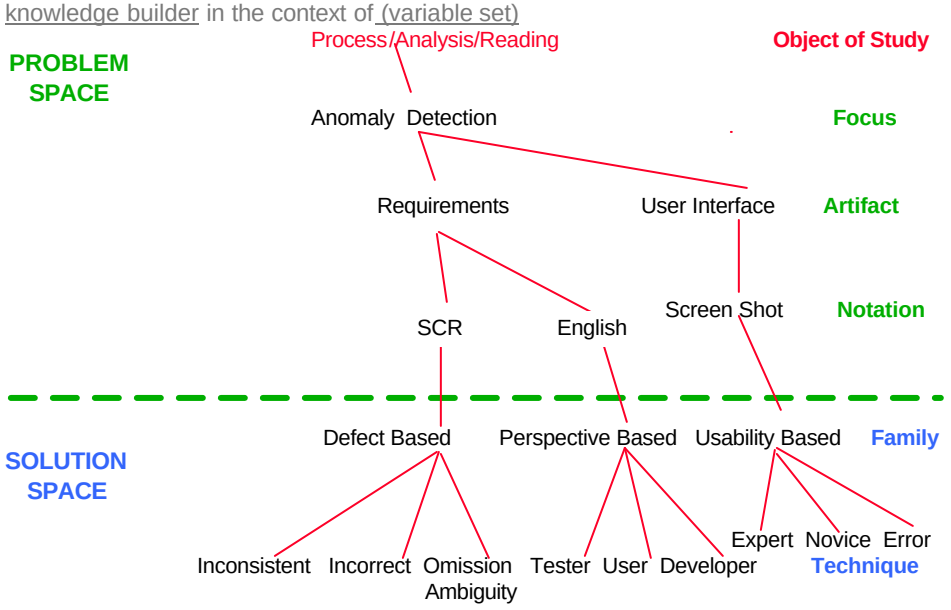


Families of Reading Techniques



Focused Families of Analysis Techniques

G3 Analyze a **set of processes focused to provide a particular coverage of an artifact** to evaluate their **ability to detect anomalies** from the point of view of the knowledge builder in the context of (variable set)



Building Laboratory Manuals

Laboratory manuals can be used to
- document processes
- provide artifacts
- offer a mix of experimental designs and analysis techniques
- provide a basis for balancing threats to validity
- support meta-analysis

Several Laboratory Manuals already exist
- Reading vs. Testing
- Defect Based Reading
- Perspective Based Reading
- Framework Reading

Several experiments have been replicated
- under the same and differing contexts
- using these manuals

Some progress has been made in doing meta-analysis

Building Laboratory Manuals

ISERN

- organized explicitly to share knowledge and experiments
- has membership in the U.S., Europe, Asia, and Australia
- represents both industry and academia
- supports the publication of artifacts and laboratory manuals

It can be used to

- help define and replicate studies and techniques
- support the development of evaluation approaches for software engineering
- contribute to the laboratory manuals.

Conclusions from Experiments

- Able to combine the results of several experiments and build up our knowledge about software processes
  - We can effectively design and study techniques that are procedurally defined, document and notation specific, goal driven, and empirically validated for use
  - We can demonstrate that a procedural approach to a software engineering task could be more effective than a less procedural one under certain conditions (e.g., depends on experience)
  - A procedural approach to reading based upon specific goals will find defects related to those goals, so reading can tailored to the environment
  - et. al.

Conclusions about Knowledge Building

- Benefit to Researchers:
  - ability to increase the effectiveness of individual experiments
  - offers a framework for building relevant practical SE knowledge
  - provides a way to develop and integrate laboratory manuals
  - generate a community of experimenters
- Benefits to Practitioners:
  - offers some relevant practical SE knowledge
  - provides a better basis for making judgements about selecting process
  - shows importance of and ability to tailor "best practices"
  - provides support for defining and documenting processes
  - allows organizations to integrate their experiences with processes