Authoring of Semantic Mathematical Content for Learning on the Web

Vortrag zur Dissertationsprüfung,
Universität des Saarlandes, 30. Juli 2012

Paul Libbrecht
paul@hoplahup.net

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Outline

- mission: authoring for ActiveMath
- related work
- my contribution
  - WYCIWYG
  - facilitating the input
  - storage & search
  - case studies
- summary
- future work

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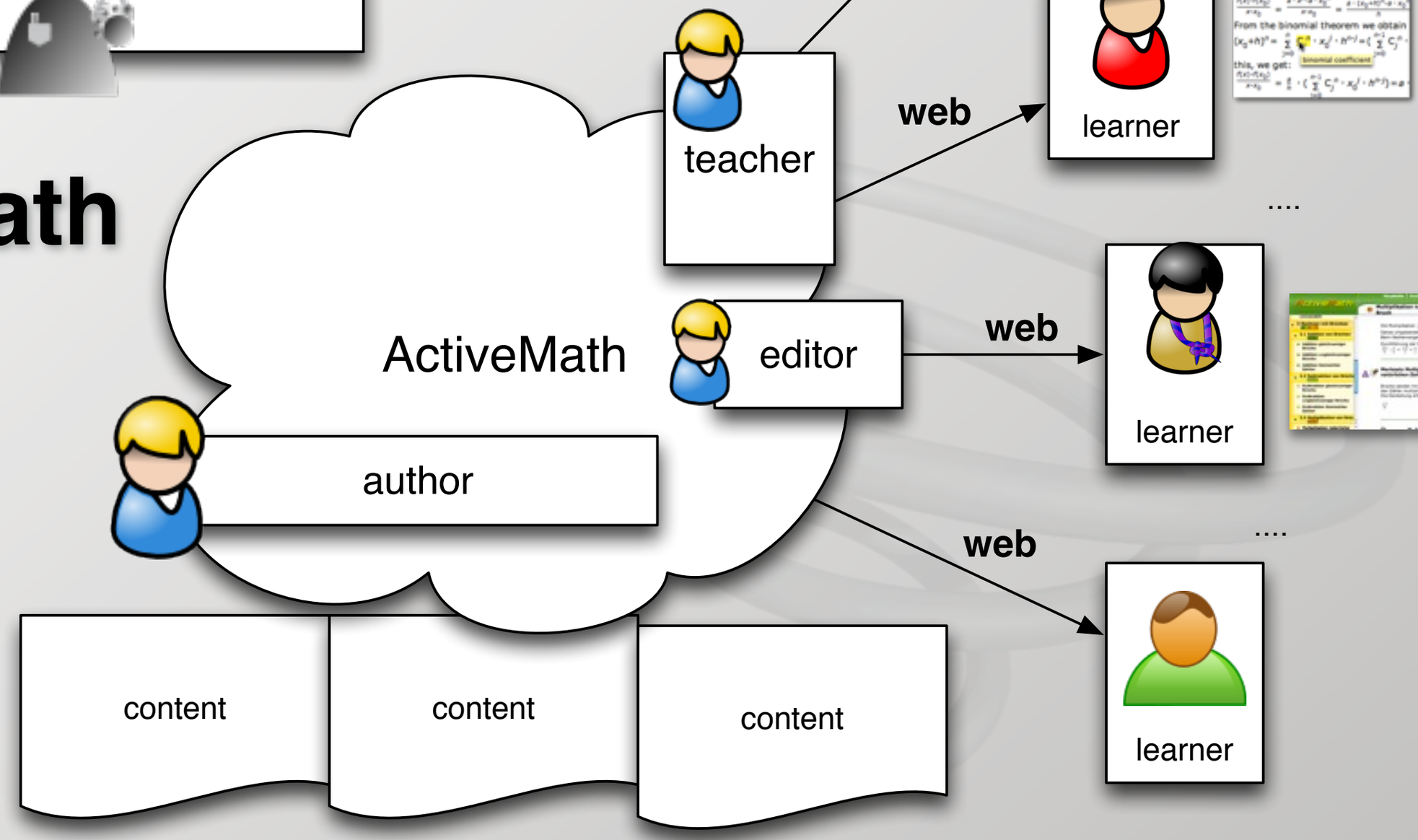
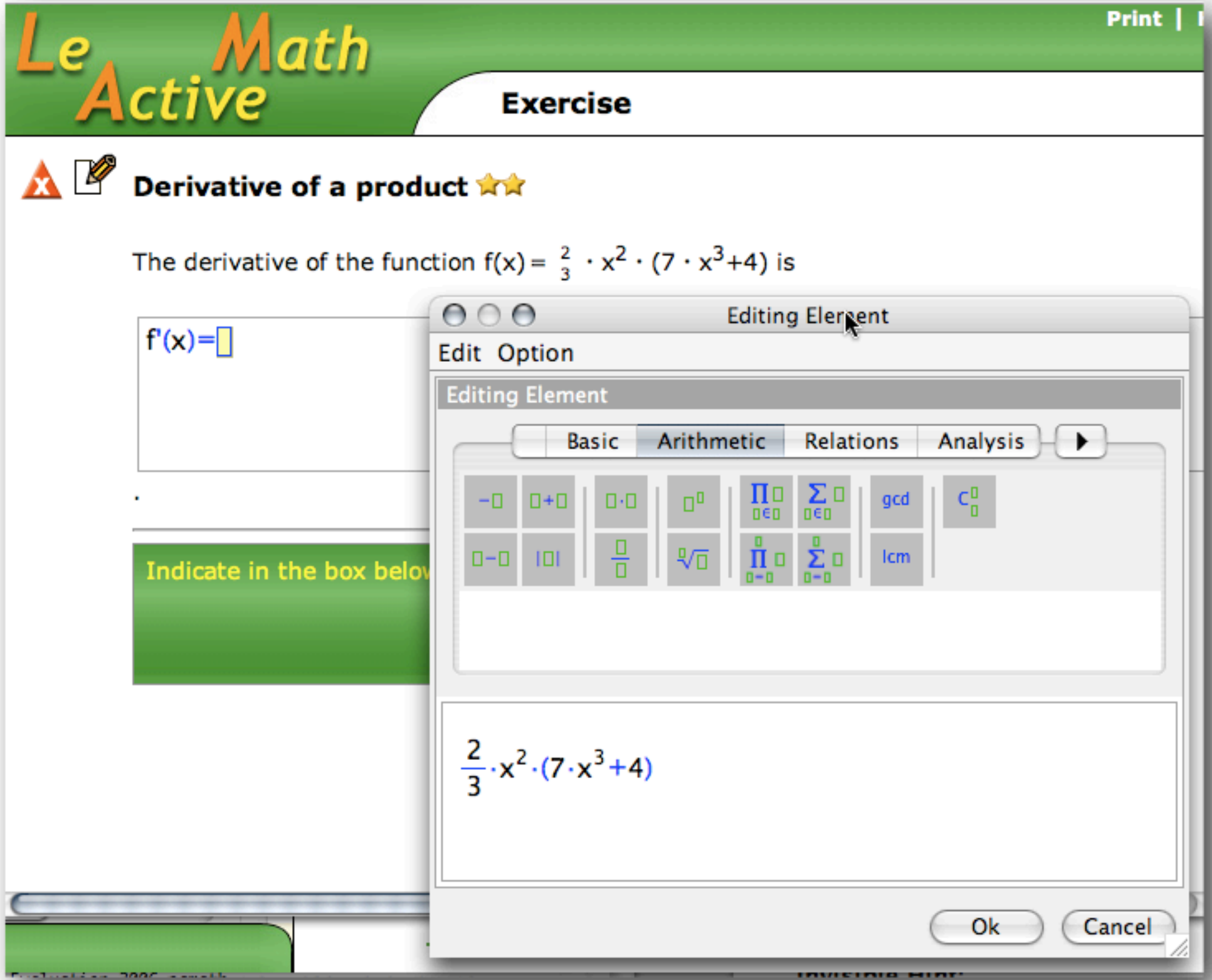
The Mission

Roles in ActiveMath



The Mission

Rol
in
Act



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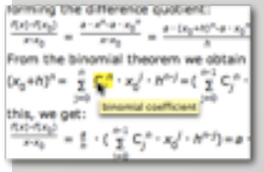


....

....

The Mission

Roles in ActiveM

....

....

forming the difference quotient:

$$\frac{f(x)-f(x_0)}{x-x_0} = \frac{a\cdot x^n-a\cdot x_0{}^n}{x-x_0} = \frac{a\cdot (x_0+h)^n-a\cdot x_0{}^n}{h}$$

From the binomial theorem we obtain

$$(x_0+h)^n = \sum_{j=0}^{n} C_j^n \cdot x_0^j \cdot h^{n-j} = (\sum_{j=0}^{n-1} C_j^n \cdot$$

binomial coefficient

this, we get:

$$\frac{f(x)-f(x_0)}{x-x_0} = \frac{a}{h} \cdot (\sum_{j=0}^{n-1} C_j^n \cdot x_0^j \cdot h^{n-j}) = a \cdot$$

The Mission

ActiveMath

Hauptseite | Suchen | Notizen | Mein Profil | Werkzeuge | Drucken | Abmelden | Hilfe

umwandeln

- 2 Rechnen mit Brüchen
  - 2.1 Addition von Brüchen
    - Addition gleichnamiger Brüche
    - Addition ungleichnamiger Brüche
    - Addition Gemischter Zahlen
  - 2.2 Subtraktion von Brüche
    - Subtraktion gleichnamiger Brüche
    - Subtraktion ungleichnamiger Brüche
    - Subtraktion Gemischter Zahlen
  - 2.3 Multiplikation von Brüc
    - Multiplikation natürlicher

Multiplikation natürlicher Zahlen mit einem Bruch

22/54

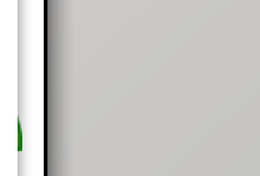
Die Multiplikation $\frac{2}{3} \cdot 6$ ergibt einen Scheinbruch von $\frac{12}{3}$, der in 4 Ganze umgewandelt wird .
Beim Rechenvorgang $\frac{2}{3} \cdot 6$ besteht die Möglichkeit, vor der Durchführung der Multiplikation zu kürzen .

$$\frac{2 \cdot 6}{3} : \frac{3}{3} = \frac{2 \cdot 2}{1} = \frac{4}{1} = 4$$

Merksatz Multiplikation von Brüchen mit einer natürlichen Zahl

Brüche werden mit einer natürlichen Zahl multipliziert, indem man den Zähler multipliziert und den Nenner unverändert lässt .
Die Darstellung erfolgt auf dem Bruchstrich :

$$\frac{1 \cdot 3}{4}$$



learner

ActiveMath Content

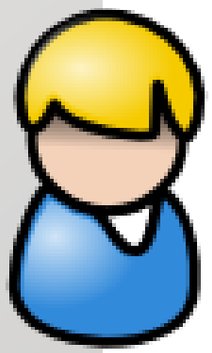
Transition to author

ActiveMath Content

EDAMTXPT

a set of items

Transition to author



ActiveMath Content

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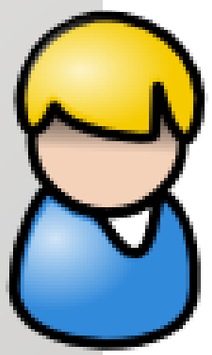

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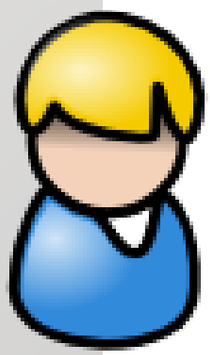

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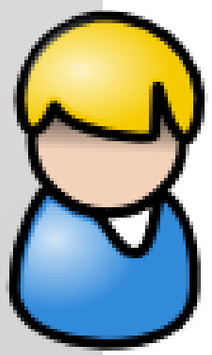

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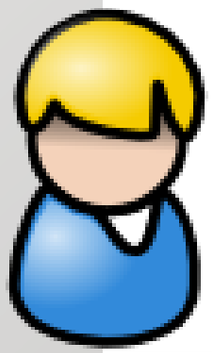

ActiveMath Content

EDAMTXPT

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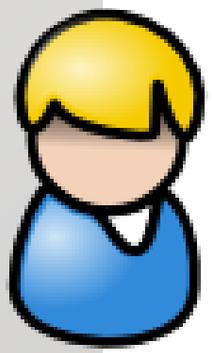
```
<example id="ex1_ab_group"
```

Transition to author



ActiveMath Content

a set of items

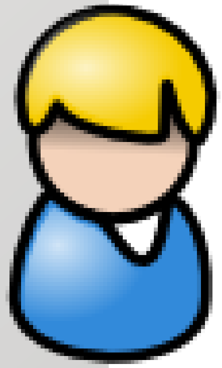
```
<example id="ex1_ab_group"

    <CMP>
                                                              Z
                                                              R
      are all examples for
      but also e.g., the set of all maps
      since these maps can be added and su
```

Transition to author

☐, ☐, ☐, and ☐ are all examples for abelian groups ,
☐ , ☐ , and

with text,



ActiveMath Content

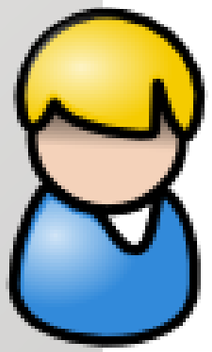
EDAMTXPT

a set of items

Transition to author

$\mathbb{Z}$, $\mathbb{Q}$, $\mathbb{R}$, and $\mathbb{C}$ are all examples for abelian groups,
$(f+g)(x) = f(x)+g(x)$, $(f-g)(x) = f(x)-g(x)$, and

with text,
with formulæ



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<example id="ex1_ab_group"

  <CMP>
    <OMOBJ><OMS cd="setname1" name="Z" /
    <OMOBJ><OMS cd="setname1" name="R" /
    are all examples for <textref  xref=
  but also e.g., the set of all maps <
  since these maps can be added and su
  <OMOBJ>
    <OMA>
      <OMS cd="relation1" name="eq" />
      <OMA>
        <OMA>
          <OMS cd="arith1" name="plus"
          <OMV name="f" />
          <OMV name="g" />
        </OMA>
        <OMV name="x" />
      </OMA>
      <OMA>
        <OMS cd="arith1" name="plus" /
        <OMA>
          <OMV name="f" />
          <OMV name="x" />
        </OMA>
        <OMA>
```

The Mission

ActiveMath Content

EDAMTXPT

a set of items

with annotations

with relations

Examples for abelian groups

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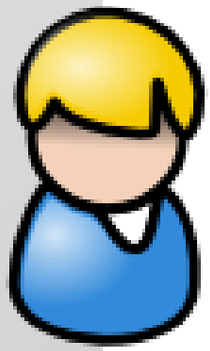
with text,
with formulæ

Transition to author



```
<example id="ex1_ab_group"
          <ref  xref="functions_symbols/fun
          <ref  xref="functions_symbols/zer
        </relation>
        <learningcontext  value="university
        <difficulty  value="medium"  />
      </extradata>
    </metadata>
     <CMP>
       <OMOBJ><OMS cd="setname1" name="Z" /
       <OMOBJ><OMS cd="setname1" name="R" /
       are all examples for <textref  xref=
       but also e.g., the set of all maps <
       since these maps can be added and su
       <OMOBJ>
         <OMA>
           <OMS cd="relation1" name="eq" />
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             <OMA>
               <OMS cd="arith1" name="plus"
               <OMV name="f" />
               <OMV name="g" />
             </OMA>
             <OMV name="x" />
           </OMA>
           <OMA>
             <OMS cd="arith1" name="plus" /
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               <OMV name="f" />
               <OMV name="x" />
             </OMA>
             <OMA>
```

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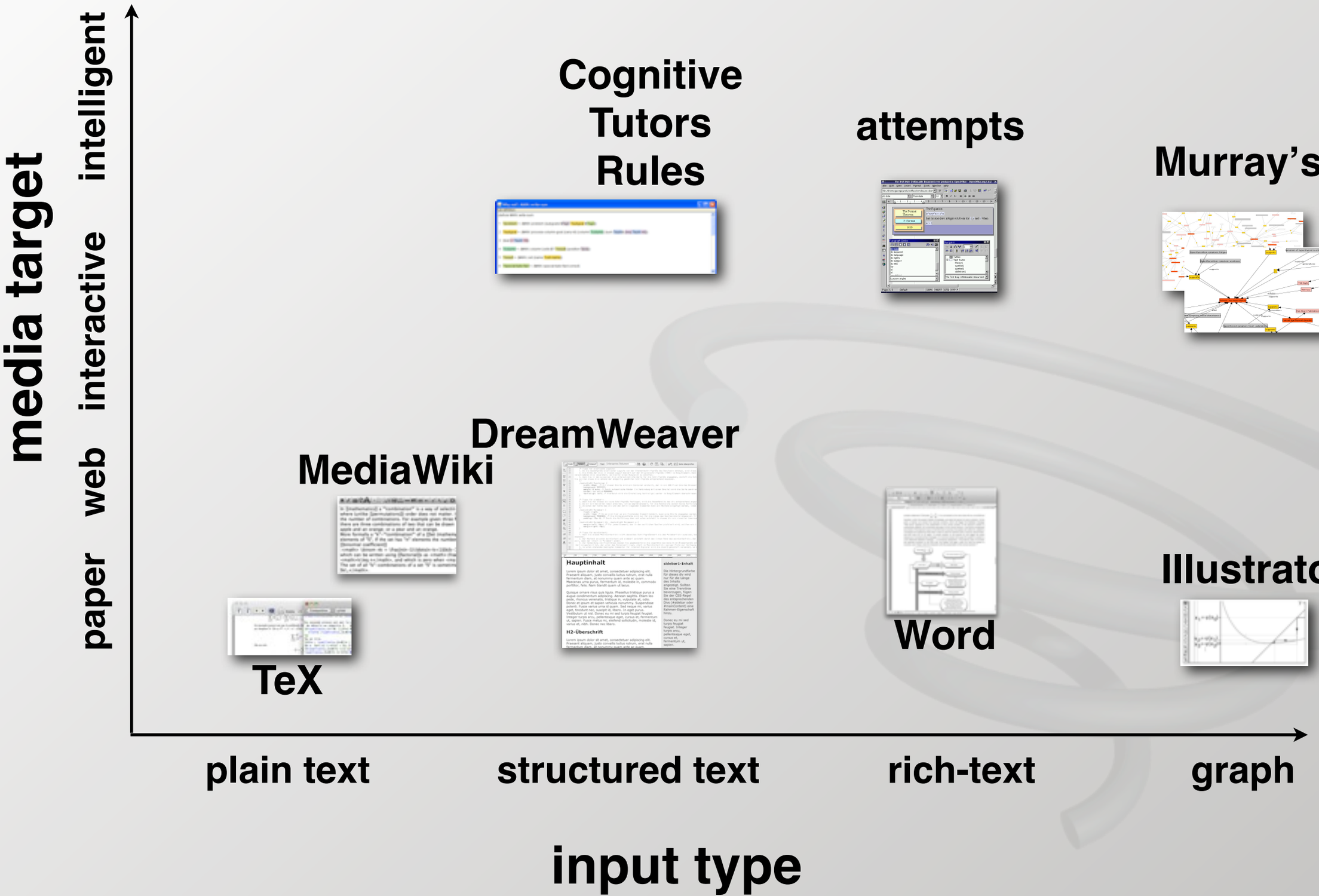
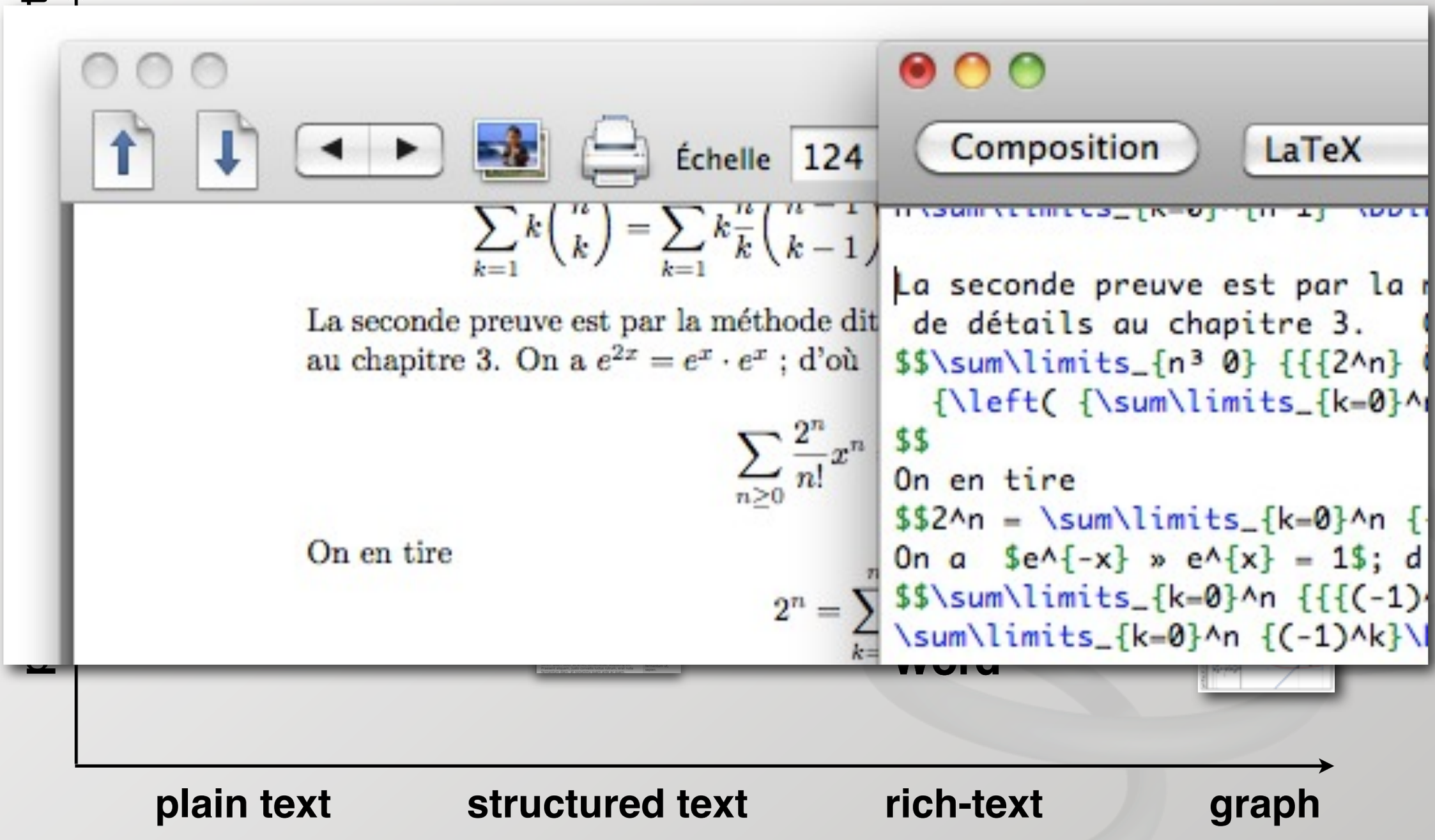
Authoring Tools

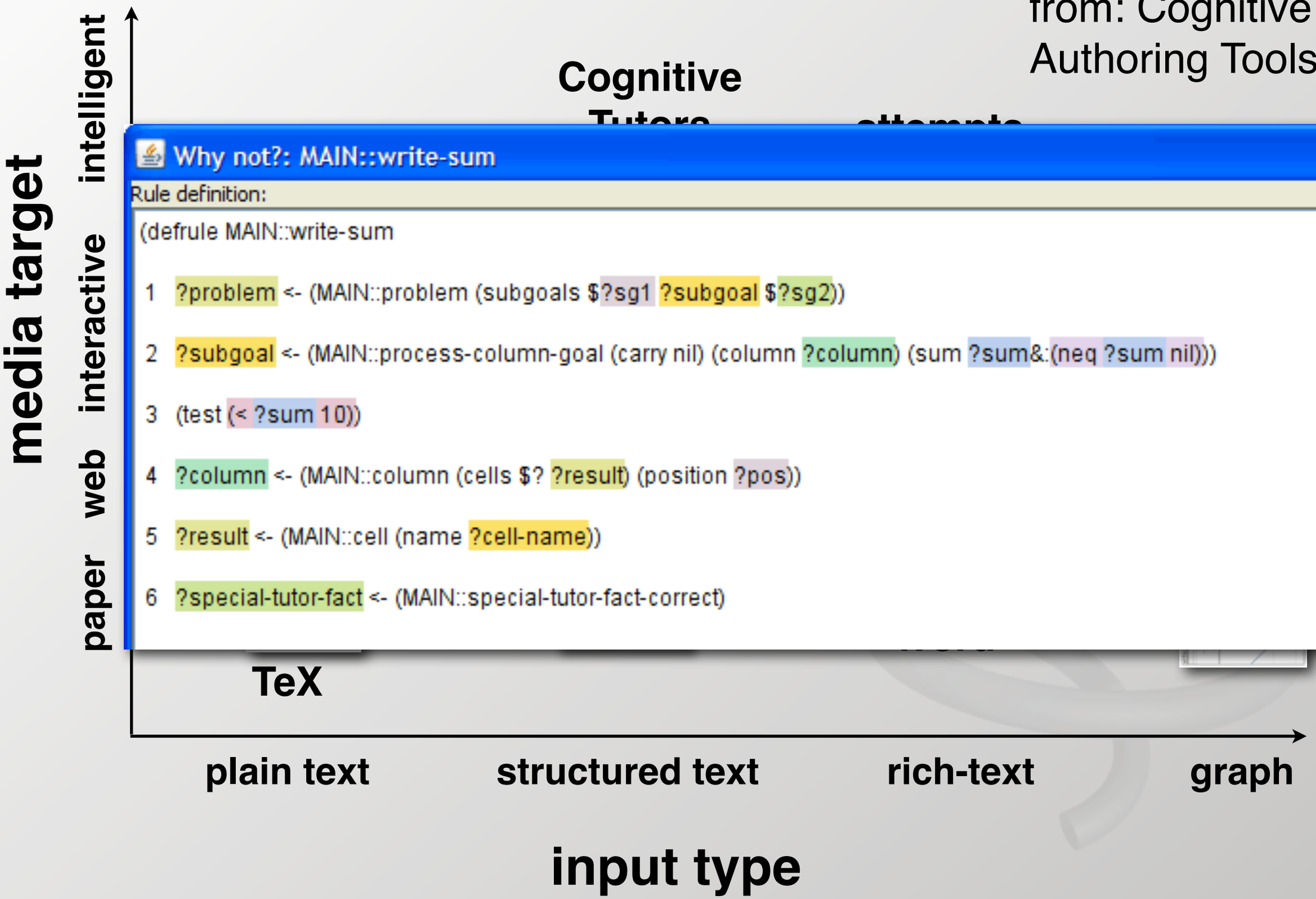


Authoring Tools TeXshop



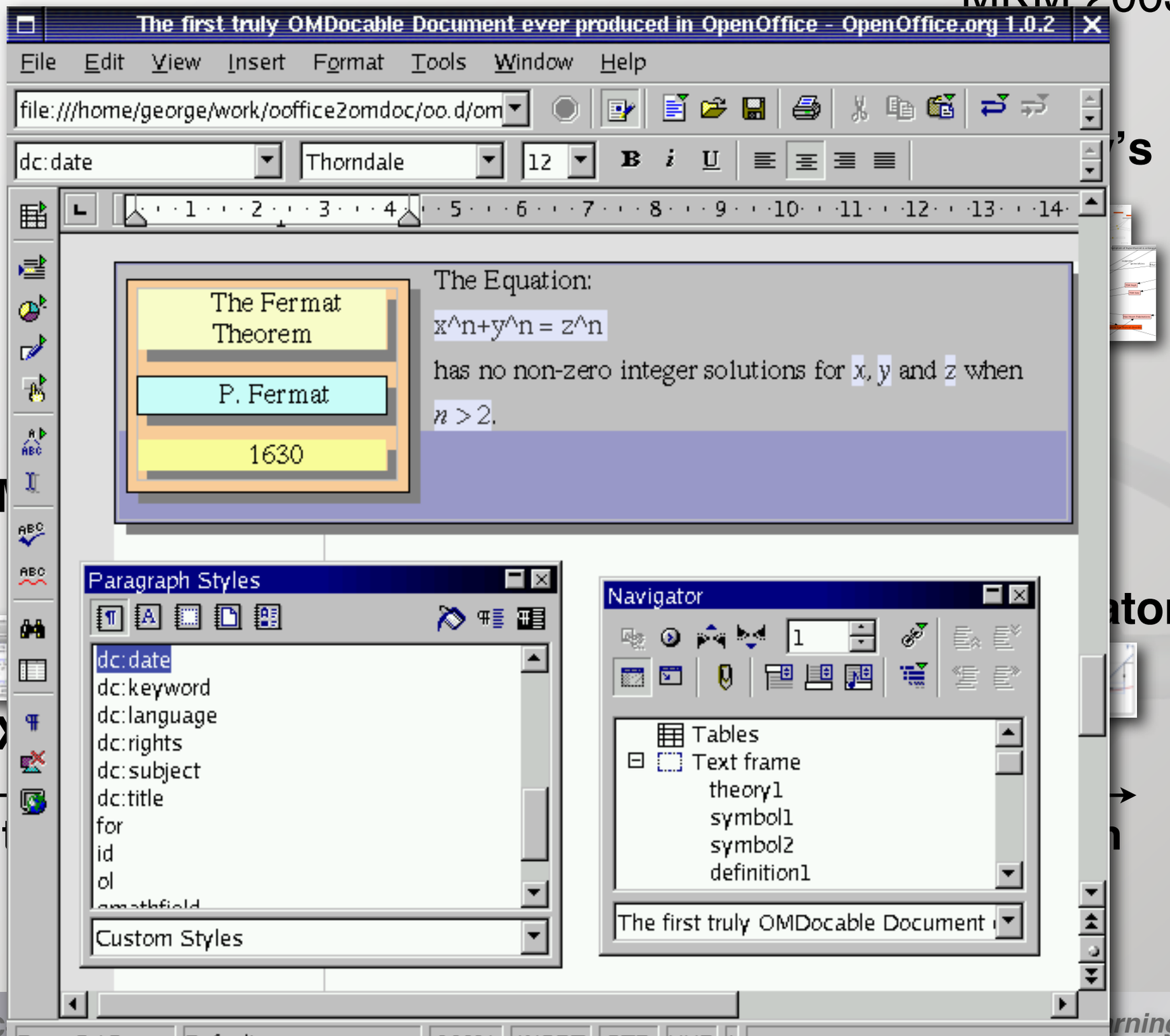
Authoring Tools: CTAT Rules

from: Cognitive Tutors' Authoring Tools' Tutorial



Authoring Tools: Word Proc.

from: Goguadze
Gonzalez-Palomo
MKM 2003



intelligent

interactive

media target

paper web

plain t

TeX

Authoring Tools

from: Murray, Woolf, Marshall
Lessons learned... ITS 2004

media target

intelligent

interactive

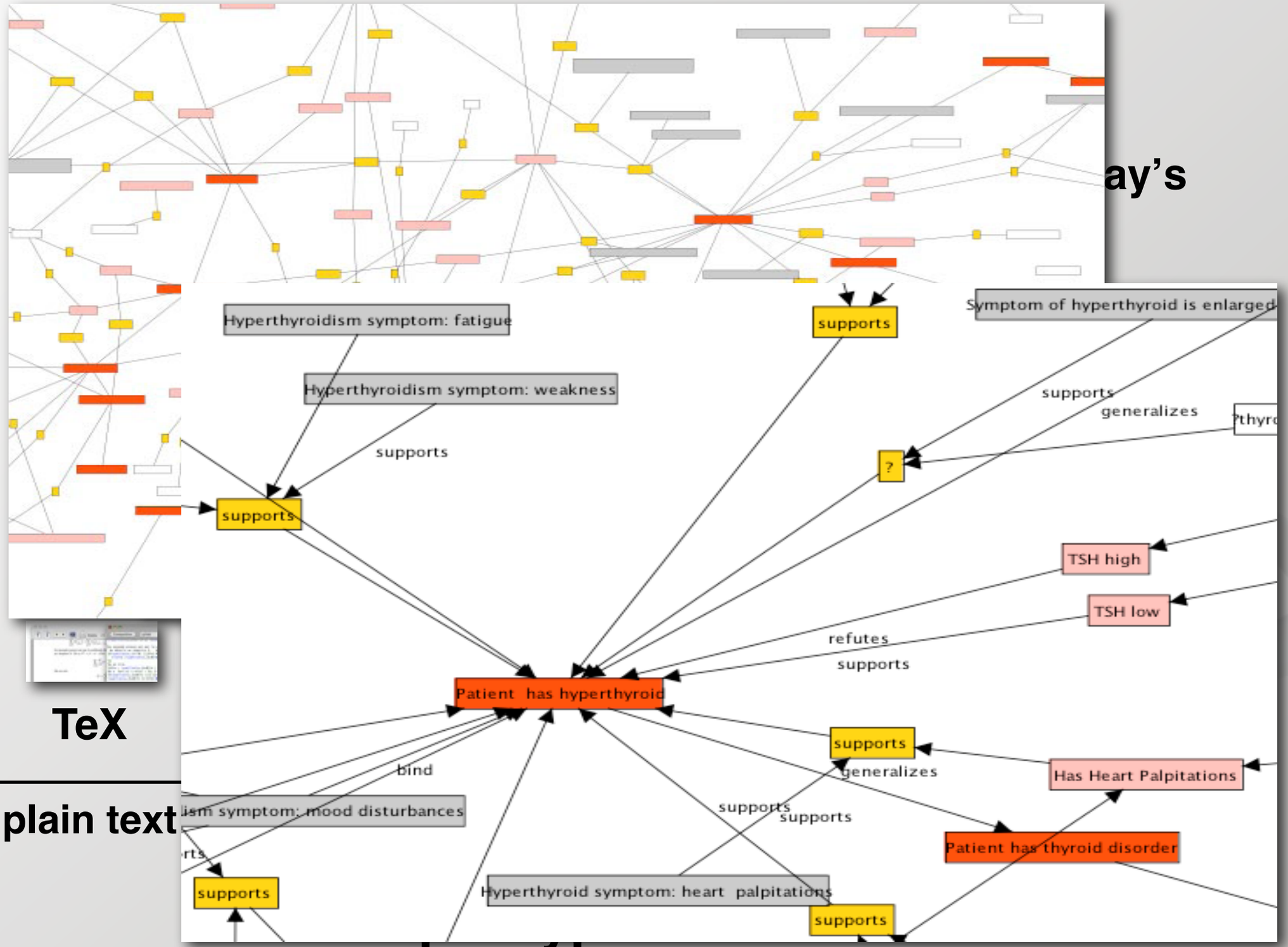
web

paper

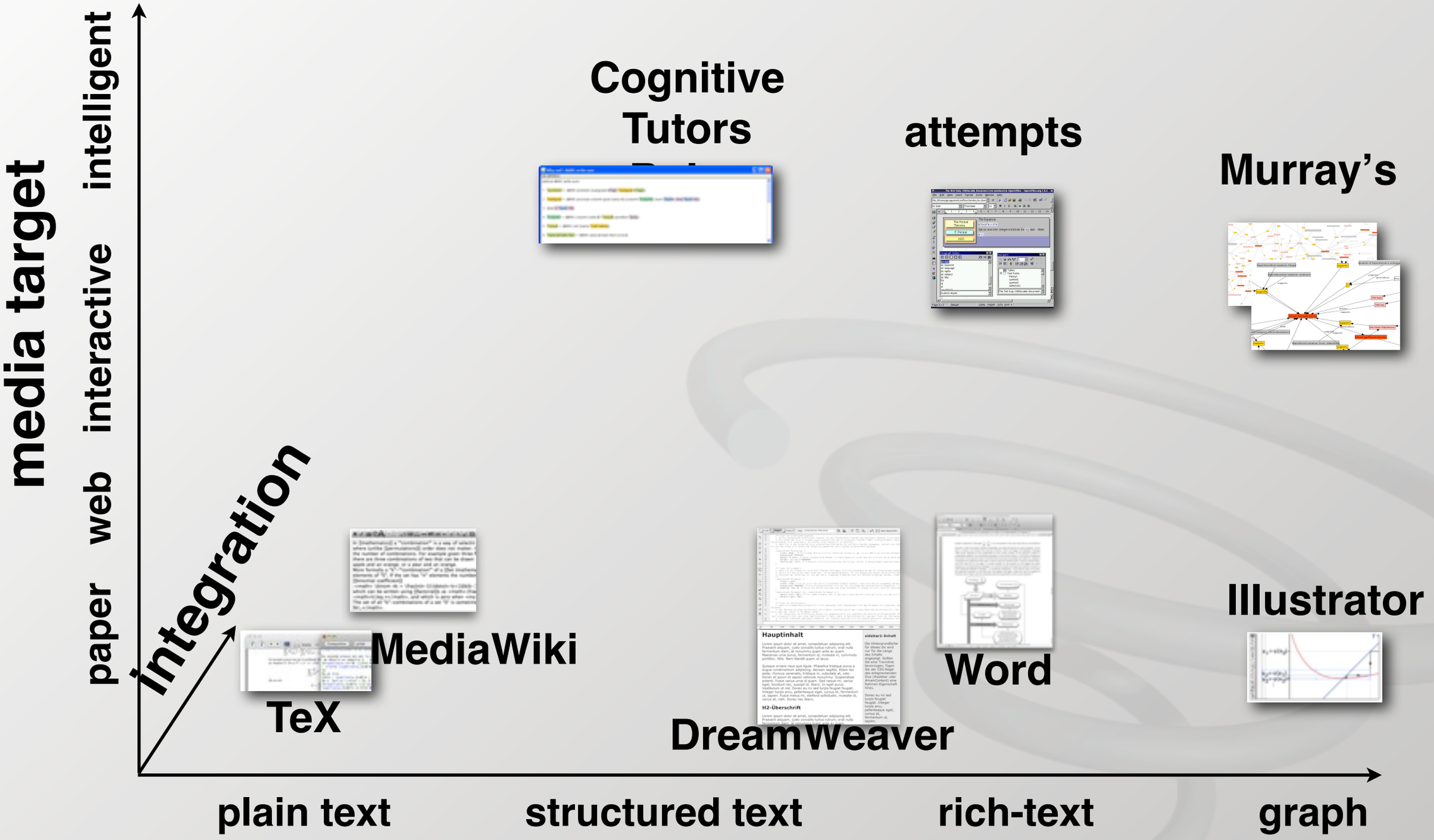
plain text

TeX

ay's



Authoring Tools



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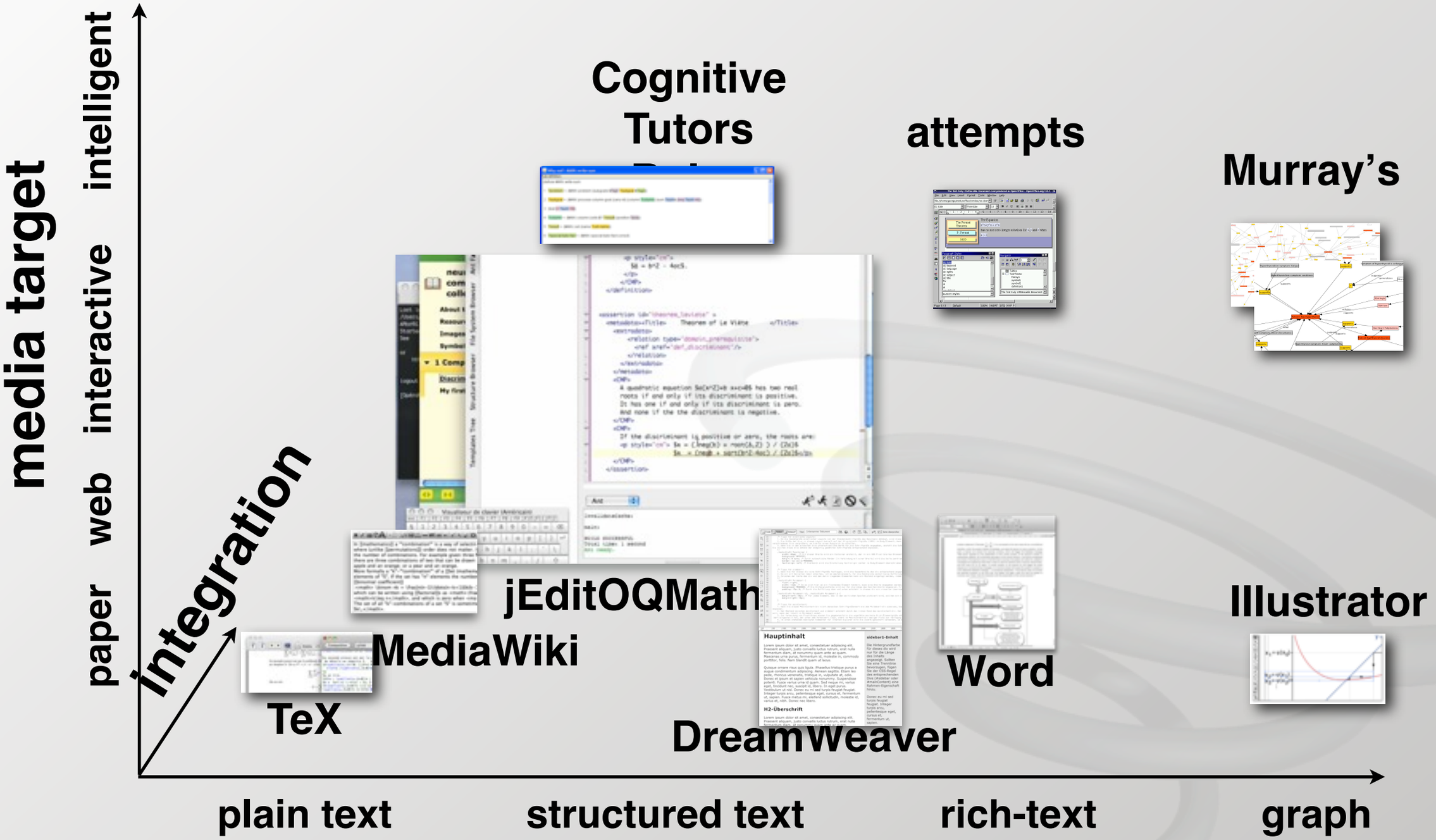

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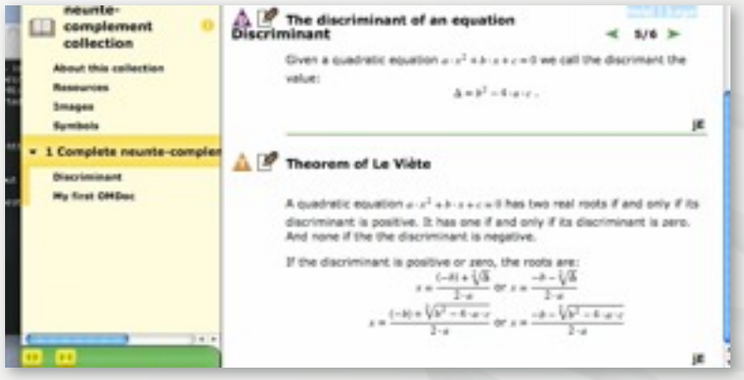
What You Check is What You Get

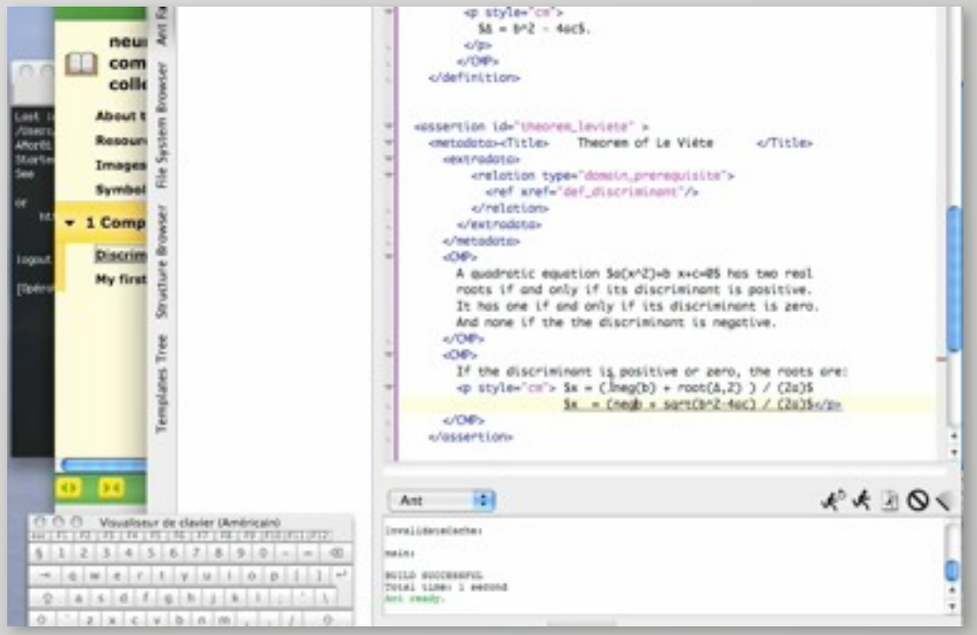
check



enhance

get

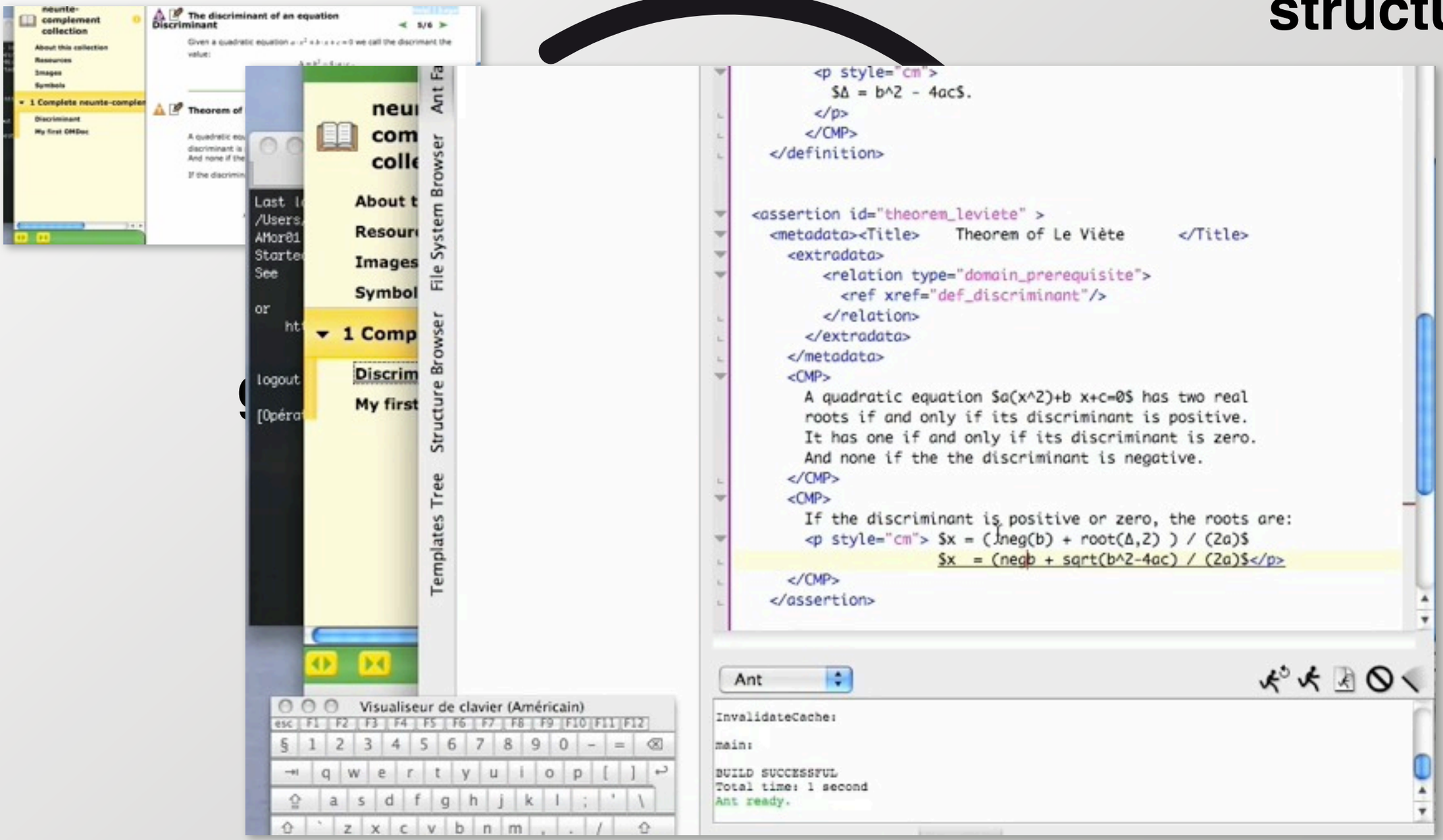
build



What You Check is What You Get

check

input
structured
text



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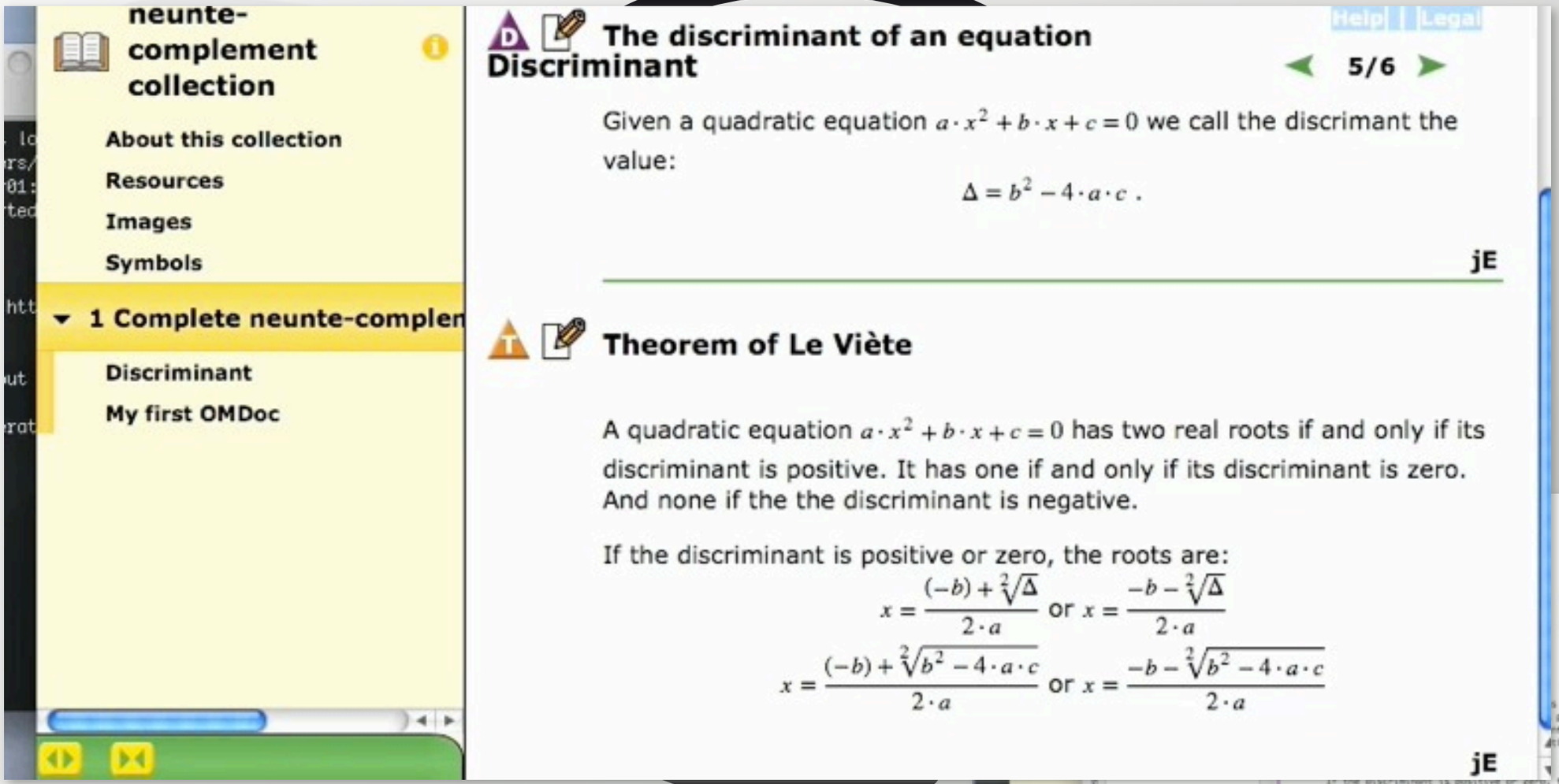
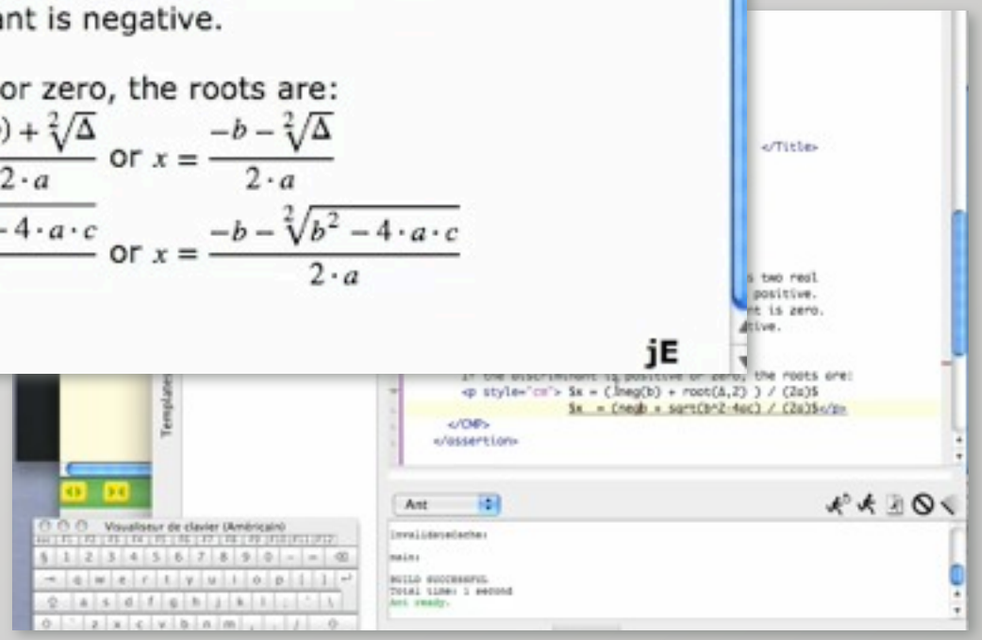


check in realistic ActiveMath

build



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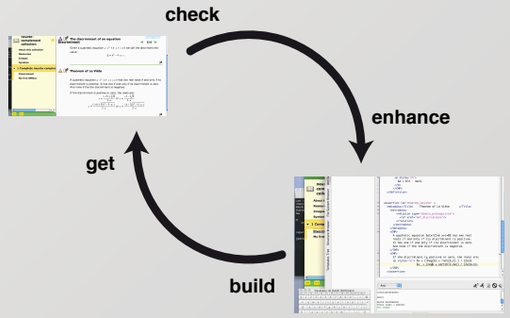
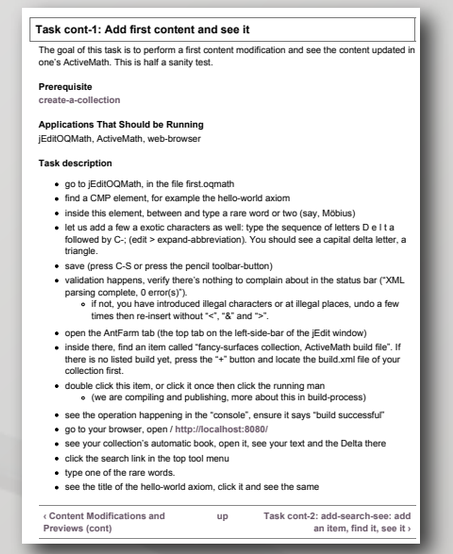
Supported Text Edition



- the source is a structured text
  - tree like, elements, texts, attributes
  - formulæ in compact format
  - kept readable at all times
- lots of XML editing support
- help to get started:
  - tutorials with exact texts
  - copy and paste of formulæ from many places:
    - some TeX
    - Wikipedia, Planet Math, MathML
  - smart paste


Task cont-1: Add first content and see it

The goal of this task is to perform a first content modification and see the content updated in one's ActiveMath. This is half a sanity test.

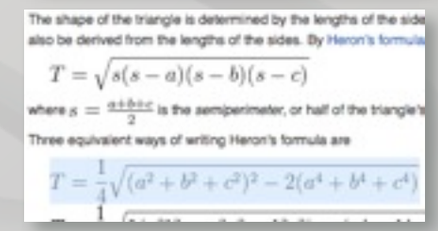
Prerequisite
create-a-collection

Applications That Should be Running
jEditOQMath, ActiveMath, web-browser

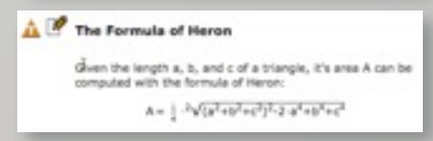
Task description

- go to jEditOQMath, in the file first.oqmath
- find a CMP element, for example the hello-world axiom
- inside this element, between and type a rare word or two (say, Möbius)
- let us add a few a exotic characters as well: type the sequence of letters D e l t a followed by C-; (edit > expand-abbreviation). You should see a capital delta letter, a triangle.
- save (press C-S or press the pencil toolbar-button)
- validation happens, verify there's nothing to complain about in the status bar ("XML parsing complete, 0 error(s)").
  - if not, you have introduced illegal characters or at illegal places, undo a few times then re-insert without "<", "&" and ">".
- open the AntFarm tab (the top tab on the left-side-bar of the jEdit window)
- inside there, find an item called "fancy-surfaces collection, ActiveMath build file". If there is no listed build yet, press the "+" button and locate the build.xml file of your collection first.
- double click this item, or click it once then click the running man
  - (we are compiling and publishing, more about this in build-process)
- see the operation happening in the "console", ensure it says "build successful"
- go to your browser, open / http://localhost:8080/
- see your collection's automatic book, open it, see your text and the Delta there
- click the search link in the top tool menu
- type one of the rare words.
- see the title of the hello-world axiom, click it and see the same

‹ Content Modifications and Previews (cont) | up | Task cont-2: add-search-see: add an item, find it, see it ›


The shape of the triangle is determined by the lengths of the side
also be derived from the lengths of the sides. By Heron's formula
$$T = \sqrt{s(s-a)(s-b)(s-c)}$$
where $s = \frac{a+b+c}{2}$ is the semiperimeter, or half of the triangle's
Three equivalent ways of writing Heron's formula are
$$T = \frac{1}{4}\sqrt{(a^2+b^2+c^2)^2 - 2(a^4+b^4+c^4)}$$


```
<assertion id="heron-formula">
  <metadata><Title>  The Formula of Heron  </Title>
  </metadata>
  <CMP>Given the length $a$, $b$, and $c$ of a triangle,
    computed with the formula of Heron:
    <p style="cm">
      $$A=1/4*sqrt((((a^2+b^2+c^2)^2-2*a^4+b^4+c^4),2)$$
    </p>
  </CMP>
</assertion>
```


The Formula of Heron

Given the length a, b, and c of a triangle, it's area A can be computed with the formula of Heron:

$$A = \frac{1}{4}\sqrt{(a^2+b^2+c^2)^2 - 2\,a^4+b^4+c^4}$$

Highlight of the thesis

Supported T

- the source
  - tree like, el
  - formulæ in
  - kept readal
- lots of XML
- help to get
  - tutorials wi
  - copy and p
    - some TeX
    - Wikipedi
- smart paste

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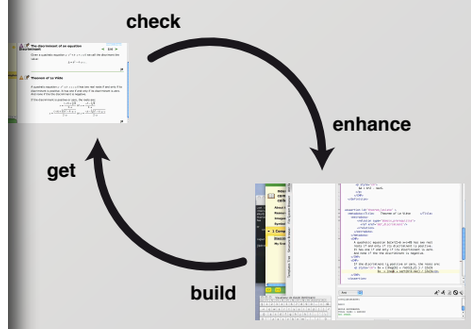

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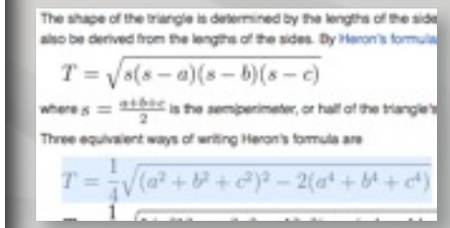
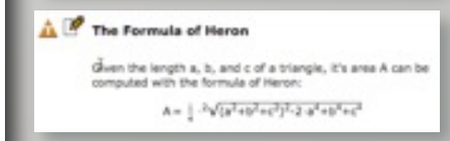




H

S

The shape of the triangle is determined by the lengths of the side
also be derived from the lengths of the sides. By Heron's formula

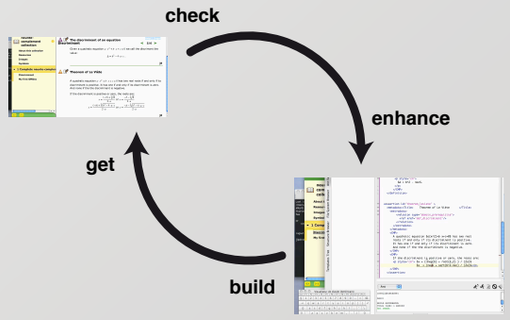
$$T = \sqrt{s(s-a)(s-b)(s-c)}$$

where $s = \frac{a+b+c}{2}$ is the *semiperimeter*, or half of the triangle's

Three equivalent ways of writing Heron's formula are

$$T = \frac{1}{4}\sqrt{(a^2+b^2+c^2)^2 - 2(a^4+b^4+c^4)}$$

$$T = \frac{1}{4}\sqrt{$$



Task cont-1: Add first content and see it

The goal of this task is to perform a first content modification and see the content updated in one's ActiveMath. This is half a sanity test.

Prerequisite
create-a-collection

Applications That Should be Running
jEditOQMath, ActiveMath, web-browser

Task description

- go to jEditOQMath, in the file first.oqmath
- find a CMP element, for example the hello-world axiom
- inside this element, between and type a rare word or two (say, Möbius)
- let us add a few a exotic characters as well: type the sequence of letters D e l t a followed by C-; (edit > expand-abbreviation). You should see a capital delta letter, a triangle.
- save (press C-S or press the pencil toolbar-button)
- validation happens, verify there's nothing to complain about in the status bar ("XML parsing complete, 0 error(s)").
  - if not, you have introduced illegal characters or at illegal places, undo a few times then re-insert without "<", "&" and ">".
- open the AntFarm tab (the top tab on the left-side-bar of the jEdit window)
- inside there, find an item called "fancy-surfaces collection, ActiveMath build file". If there is no listed build yet, press the "+" button and locate the build.xml file of your collection first.
- double click this item, or click it once then click the running man
  - (we are compiling and publishing, more about this in build-process)
- see the operation happening in the "console", ensure it says "build successful"
- go to your browser, open / http://localhost:8080/
- see your collection's automatic book, open it, see your text and the Delta there
- click the search link in the top tool menu
- type one of the rare words.
- see the title of the hello-world axiom, click it and see the same

‹ Content Modifications and Previews (cont) up Task cont-2: add-search-see: add an item, find it, see it ›

```
<assertion id="heron-formula">
  <metadata><Title>     The Formula of Heron      </Title>
    </metadata>
    <CMP>Given the length $a$, $b$, and $c$ of a triangle,
      computed with the formula of Heron:
      <p style="cm">
        $A=1÷4*√(((a^2+b^2+c^2)^2-2*a^4+b^4+c^4),2)$
      </p>

      </CMP>
  </assertion>
```

The Formula of Heron

Given the length a, b, and c of a triangle, it's area A can be computed with the formula of Heron:

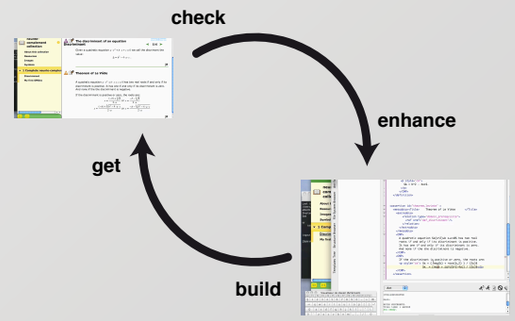
$$A = \frac{1}{4} \cdot \sqrt{(a^2+b^2+c^2)^2 - 2 \cdot a^4+b^4+c^4}$$

- Wiki

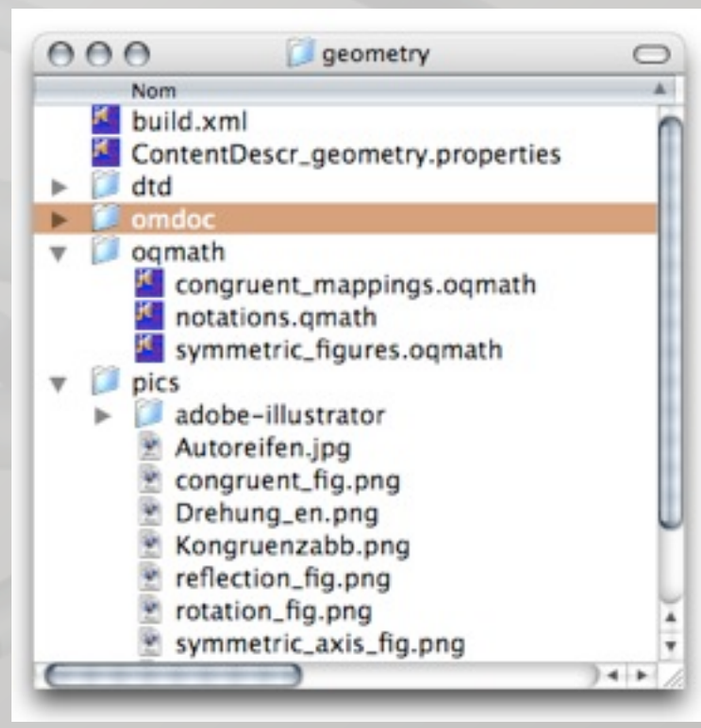
Outline

- mission: authoring for ActiveMath
- related work
- my contribution
  - WYCIWYG
  - facilitating the input
  - storage & search
  - case studies
- summary
- future work

Content Storage

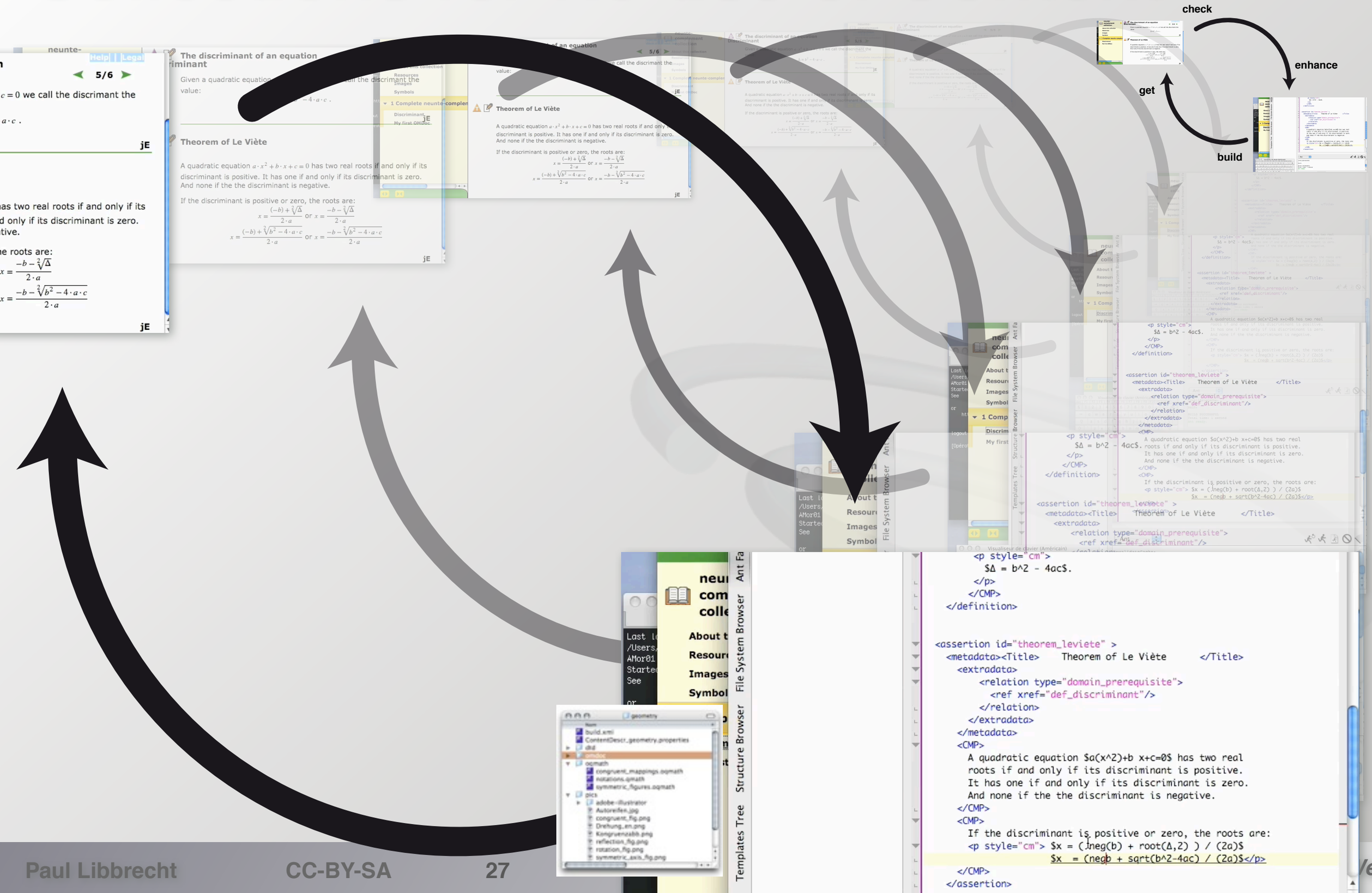


- authors create files
- the files are indexed
  - ActiveMath can serve the content items
- short build cycles:
  - need to check now!
  - ready to serve high-performance
- files are in collections
  - authors know what is where
  - directory with simple organization
  - can be shared



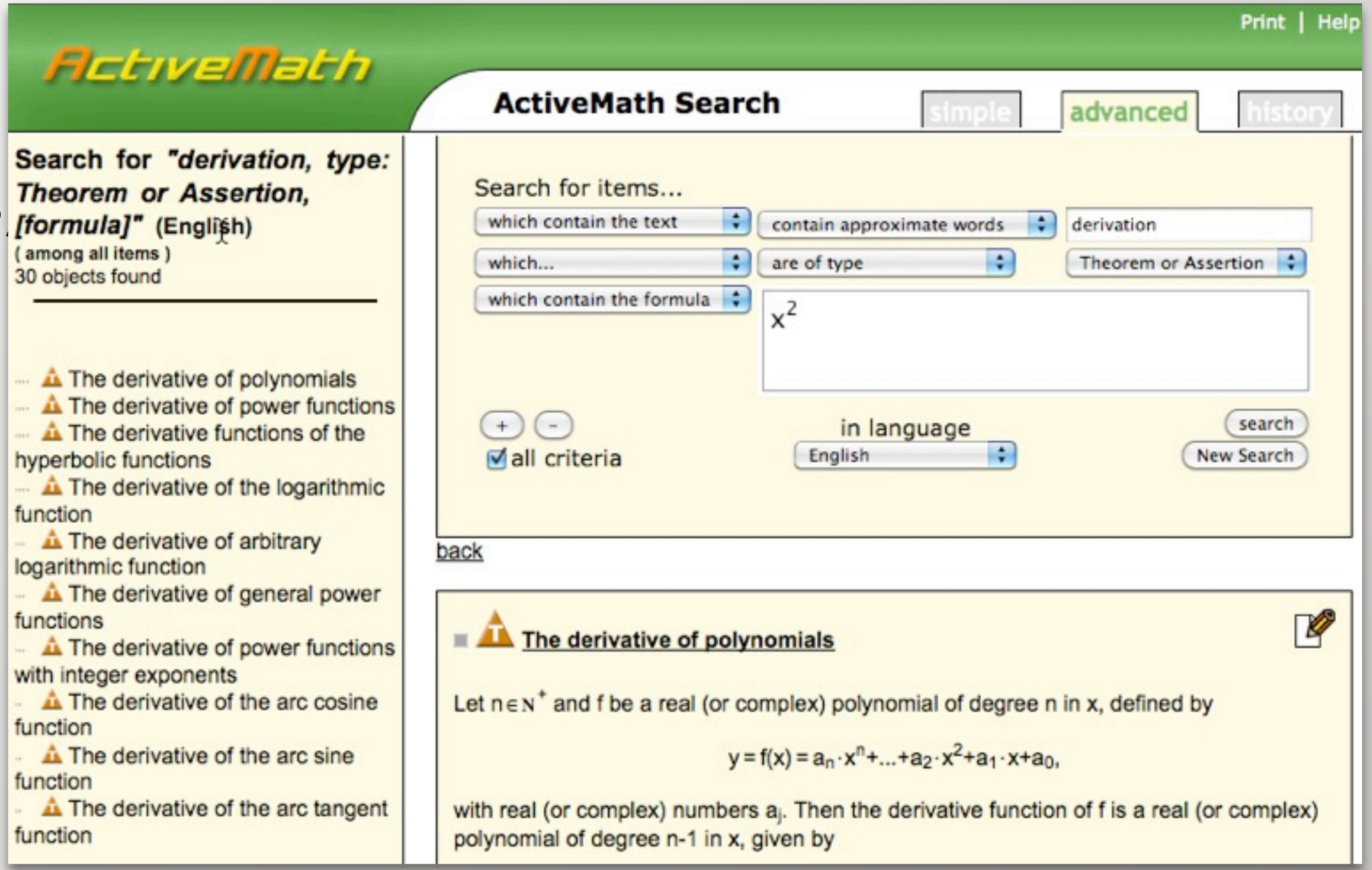
Many WYCIWYG Cycles

Collections for Re-use of Content



Search

- a tool for learners and authors
- search for text, attributes, formulæ
- display content items, find seen places



Search

- a tool for learners and authors
- search for text, attributes, formulæ
- display content items, find places
- how does it work?
  - an *index* notes occurrences of each word
  - ranking through:
    - precision to query (title, stemming)
    - desirability for learner
  - formulæ are made into phrases

Search

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presentation
Arithmetic exercise
Let us assume
$a+b=k$

- how does it work?
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Search

- a tool for lea
- search for te
- display cont

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OQMath
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Search

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- how
  - an *in*
  - rank
    - pr
    - de
  - form

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<CMP>Let us assume $a+b=k$.</CMP>

OMDoc
<title>Arithmetic exercise</title>
<CMP>Let us assume
<OMOBJ><OMA> <OMS cd=relation1 name=eq/>
<OMA><OMS cd=arith1 name=plus/>
<OMV name=a/><OMV name=b/>
</OMA>
<OMV name=k/>
</OMA>
.</CMP>

Search

- a tool for learners and auth
- search for te
- display cont
  - pr
  - de
- form

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OQMath
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indexed tokens
title-en: arithmet exercis
text-en: let us assum _(_0 _OMS_relation1/eq
_(_1 _OMS_arith1/plus _OMV_a _OMV_b _)_1 _OMV_k _)_0
phonetic-en: LT AS ASM

<OMA><OMS cd=arith1 name=plus/>
<OMV name=a/><OMV name=b/>
</OMA>
<OMV name=k/>
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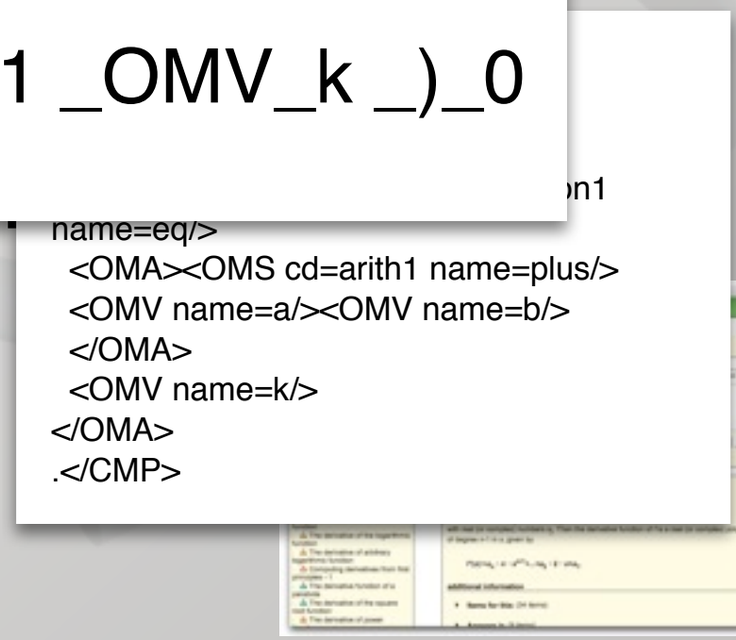

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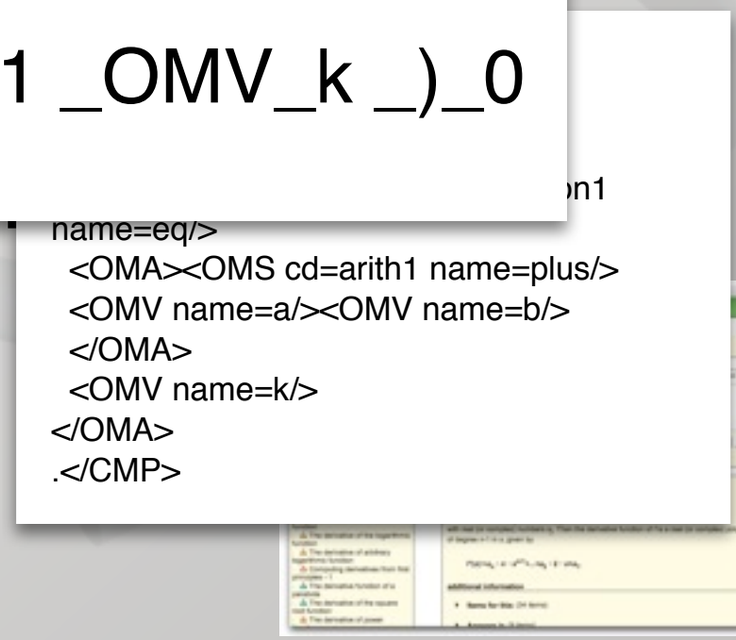
query
arithmetic



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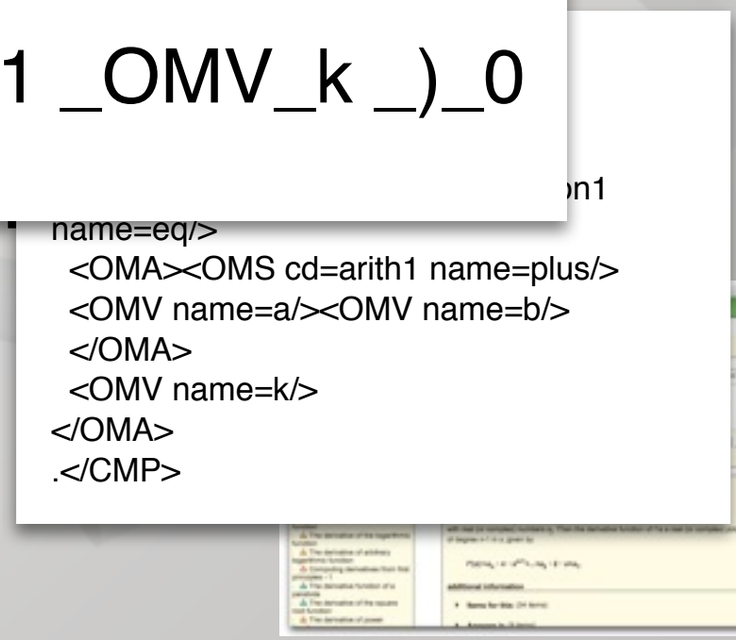

query
arithmetic

query
asume

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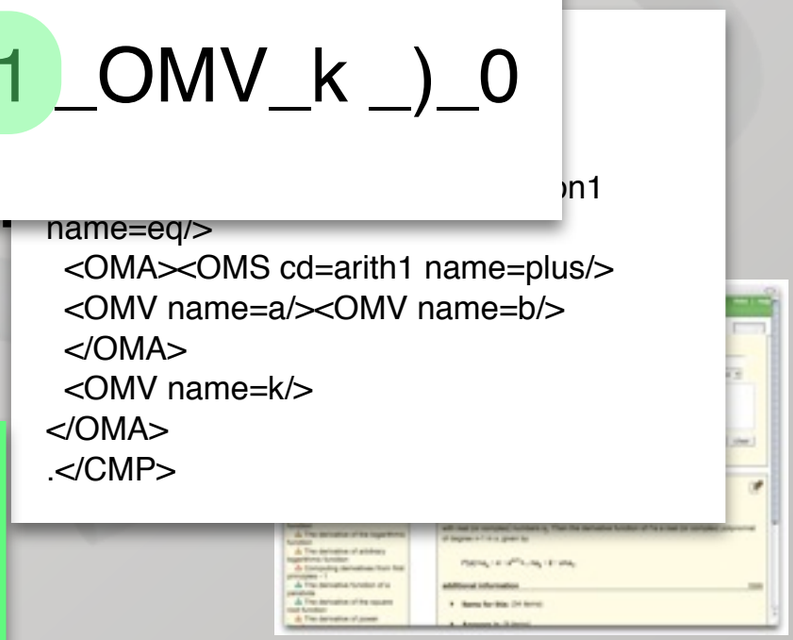

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query
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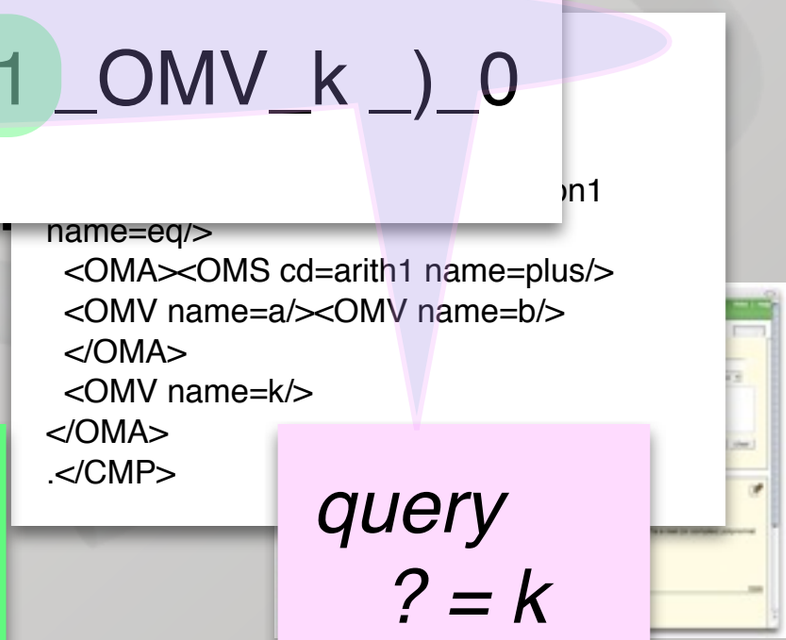

query
arithmetic

query
asume

query
a+b

query
? = k

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  - facilitating the input
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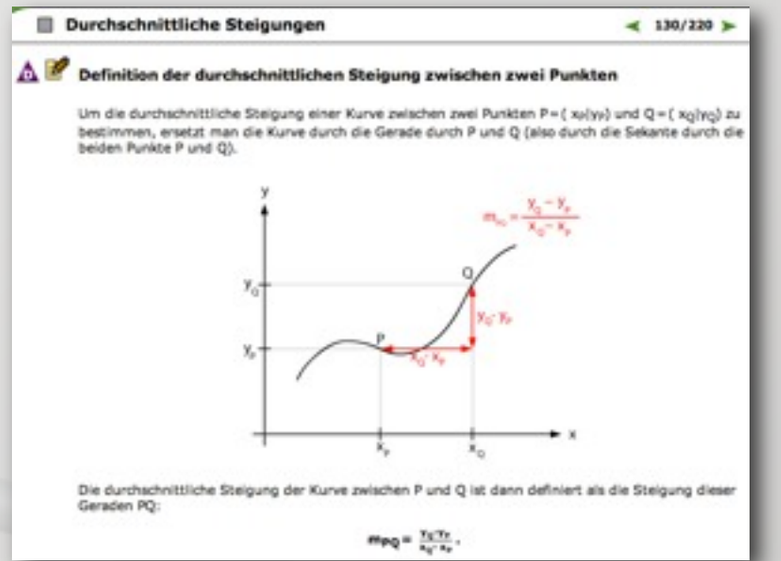
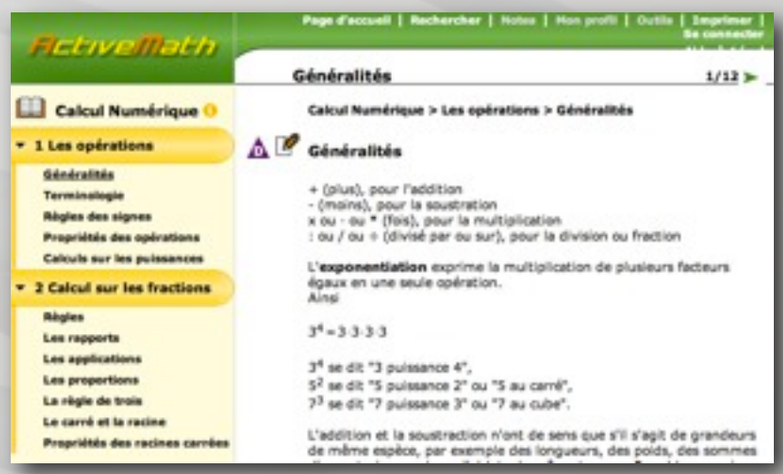
  - **case studies**
- summary
- future work

Case studies: Authors' Achievements

- no formal experiment
- but long *coaching* of authors
  - e.g. Christian
    - mathematician, TeX-guy
    - strong organization of content
  - e.g. Adrien
    - young developer,
    - full self-learner from tasks
  - meeting intelligent features...
- tool used by ~50 authors
  - who created ~20000 items



400 pages



20 pages

Lessons Learned

- task descriptions
  - no imprecision allowed
  - effective to jumpstart
- tangible authoring crucial
  - all: utility of features only if it works
  - far-away expectations ignored
  - short attempt cycles to grasp meaning
- freedom to organize sources
  - author-*important* information at visible places
  - inheritance model

Features of an authoring tool (Murray 2003)

- visual editing and rapid testing
- flexible opportunistic design
- modularity, re-usability
- familiar paradigms
- scriptability, customization

Features of an authoring tool

- visual editing and rapid testing
  - *no WYSIWYG but strong rapid testing*
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- scriptability, customization
  - *source text editing, configurable notations*

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Future work

- visual tool
  - remember: *easy input but hard management*
  - architecture and component to be re-used
    - reload, search, CnP, ...
- fuzzy math search
  - normalization and rewriting systems exist
  - should x^2-1 match (x-1)(x+1) ?
- testable intelligent components
  - as easy as a WYCIWYG cycle
    - restart course-planning with same user-model

thank you.

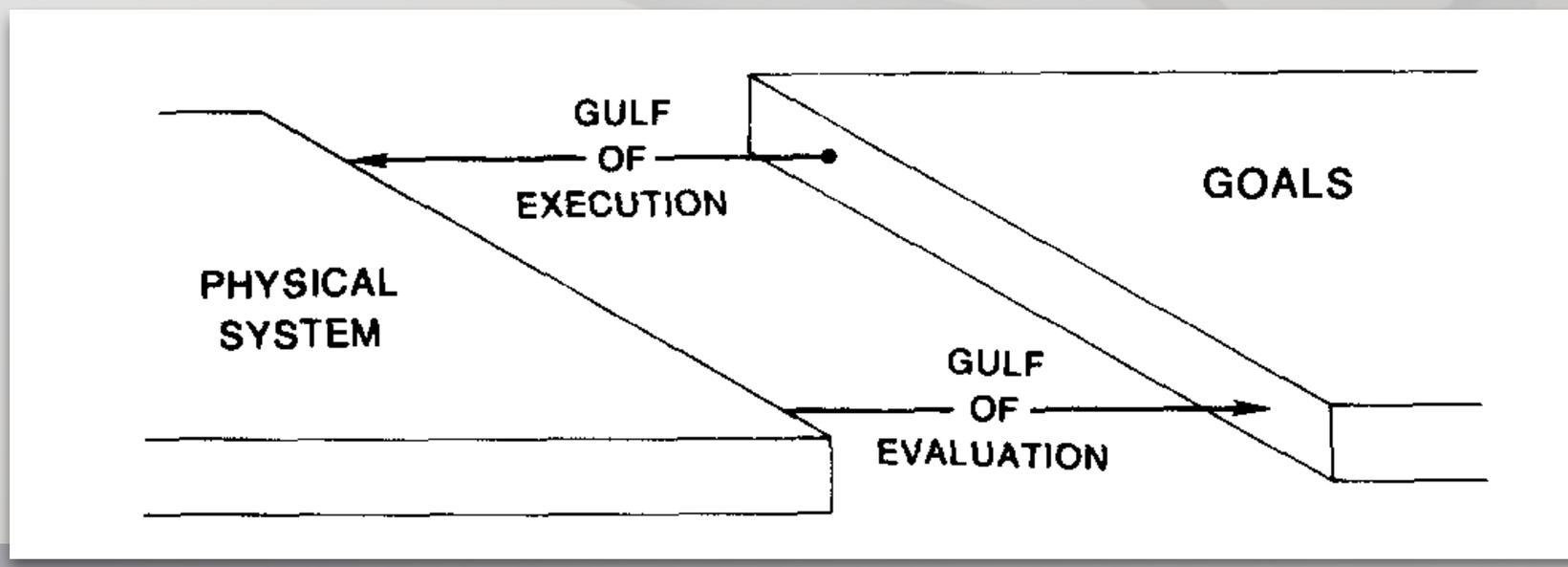
supplementary

Editing XML Source is not Easy

- text source editing:
  - is common and for all skill-levels
  - can be exchanged in emails, etc
  - is versioning-system friendly
- XML editing:
  - is much better supported than many other languages (e.g. QMath or wiki)
  - can be kept readable (read: OMDoc book)
  - multiple editors, standardized validation

Direct Manipulation

- Easy?
  - *look at direction manipulation*
  - he formulated „against programming“
  - but a more detailed analysis (Fröhlich 1996)
    - Visualisation of output data seems critical to the benefits of direct manipulation
    - Visualisation of input data may be less important
- Gulf of evaluation



Storage Performance

- focus: fast serving
  - beyond 2000 queries/second
- indexing may take time:
  - LeAM_calculus: old CPU, ~20 minutes
  - new CPU: ~2 minutes
  - 1000 books? ~15 hours
  - comparable to big deployments
- focus for authors: fast reload
  - only reloads changed files
  - motto: keep files small

Copy and Paste for Learners

- for students as well
- based on drag-and-drop of links

- evaluation: unthinkable!
- conclusion: standards

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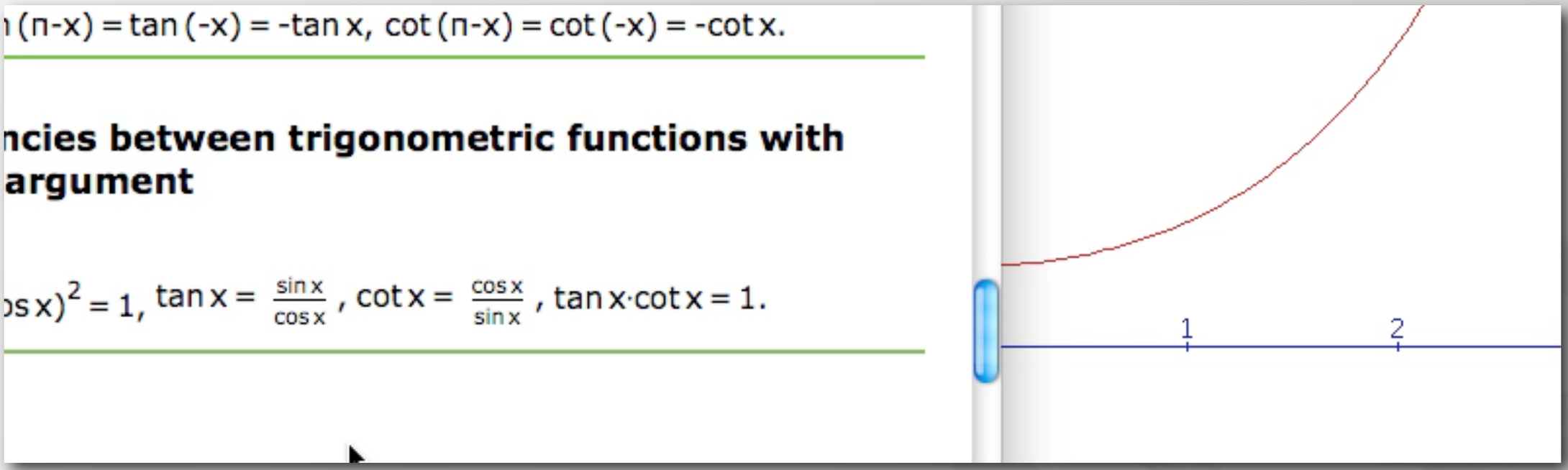

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- conclusion: standards
  - observe discrepancies
  - MicroSoft - DesSci: simili-agreement
  - MathML 3 chapter 6
  - IETF mailing-list: name clipboard flavors

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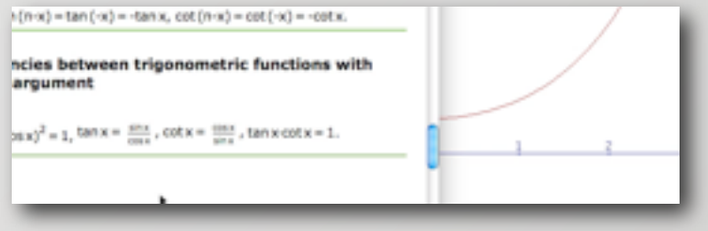

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Authoring for Artificial Intelligence

- in ActiveMath, AI includes:
  - Belief Network Model as the learner-model
    - authors should try to simulate
  - Hierarchical Task Network Planner
    - authors should make sure the course generation delivers sensible courses
  - CAS-evaluation of exercises
    - authors should anticipate answers and make sure evaluation works
  - ranking of search
    - anticipate queries and verify

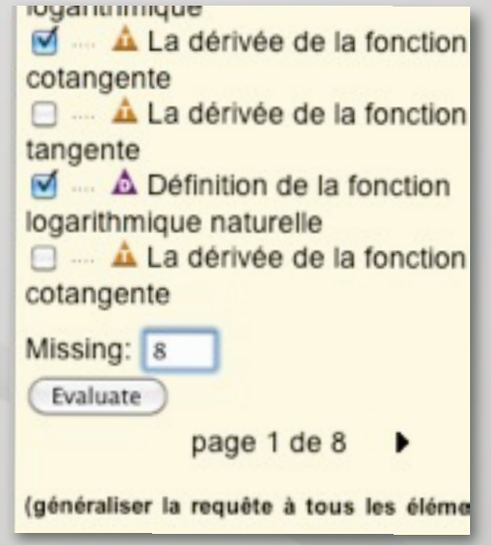
Authoring for Artificial Intelligence

- approach thus far:
  - limit to knowledge-explanation
  - ==> too theoretical
  - obtain strategies by (strict) interviews
- contribution:
  - limit size of medata input by inheritance
- future: testable intelligence
  - introspectable user-model
  - reporting course-generation
  - ...

Search Test Suite

- objective:
  - raise utility of the search engine
  - precision: «low-amount of noise»
  - recall: «percentage rightly found»
- created by domain experts
- with books they know well

verbindungsgesetz	0,5	1,0	*	0.083333336	1,0
assoziativgesetz Bruchrechnung	0,0	NaN	*	0,0	0,0
Zehnerbruch	1,0	1,0	*	0.16666667	1,0
Bruch in Dezimalzahl	0,5	1,0	*	0.083333336	1,0
bruch in dezimalzahl umwandeln	1,0	1,0	*	0.25	1,0
periode	1,0	1,0	*	0,05	1,0



	2006 LeAM English	2009 SchulM	2010 SchulM	2010 LeAM Spanish	2010 Kassel
precision	93 %	12 %	53 %	79 %	78 %
recall	63 %	81 %	85 %	87 %	84 %