Towards A Community of Practice Toolkit Based On Semantically Marked Up Artifacts

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Mathematical Knowledge Management (MKM)

- **Mathematical Knowledge (MK)** is abstract, universal, highly structured, extraordinary interconnected, and of immense size
- Mathematics is in *a state of transition* (from pen & paper to ICT-based communication)
- **MKM** is a *new emerging interdisciplinary field* of research; supporting the ...
  - Articulation
  - Organization
  - Dissemination
  - Access
- **Mathematical Practice** defines requirements for MKM technologies; **MKM technologies** transforms the way mathematics is practiced

cf. Mathematical Knowledge Management by William Farmer [Far05, Far04]

Outline

1. MKM Technologies
2. Communities of Practice
3. CoPfolios: Collaborative Models
   - Standards for Representing Mathematical Knowledge
   - CoPfolio Examples
4. CoPit: A toolkit for Managing CoPfolios
5. Case Study
6. Outlook & Conclusion

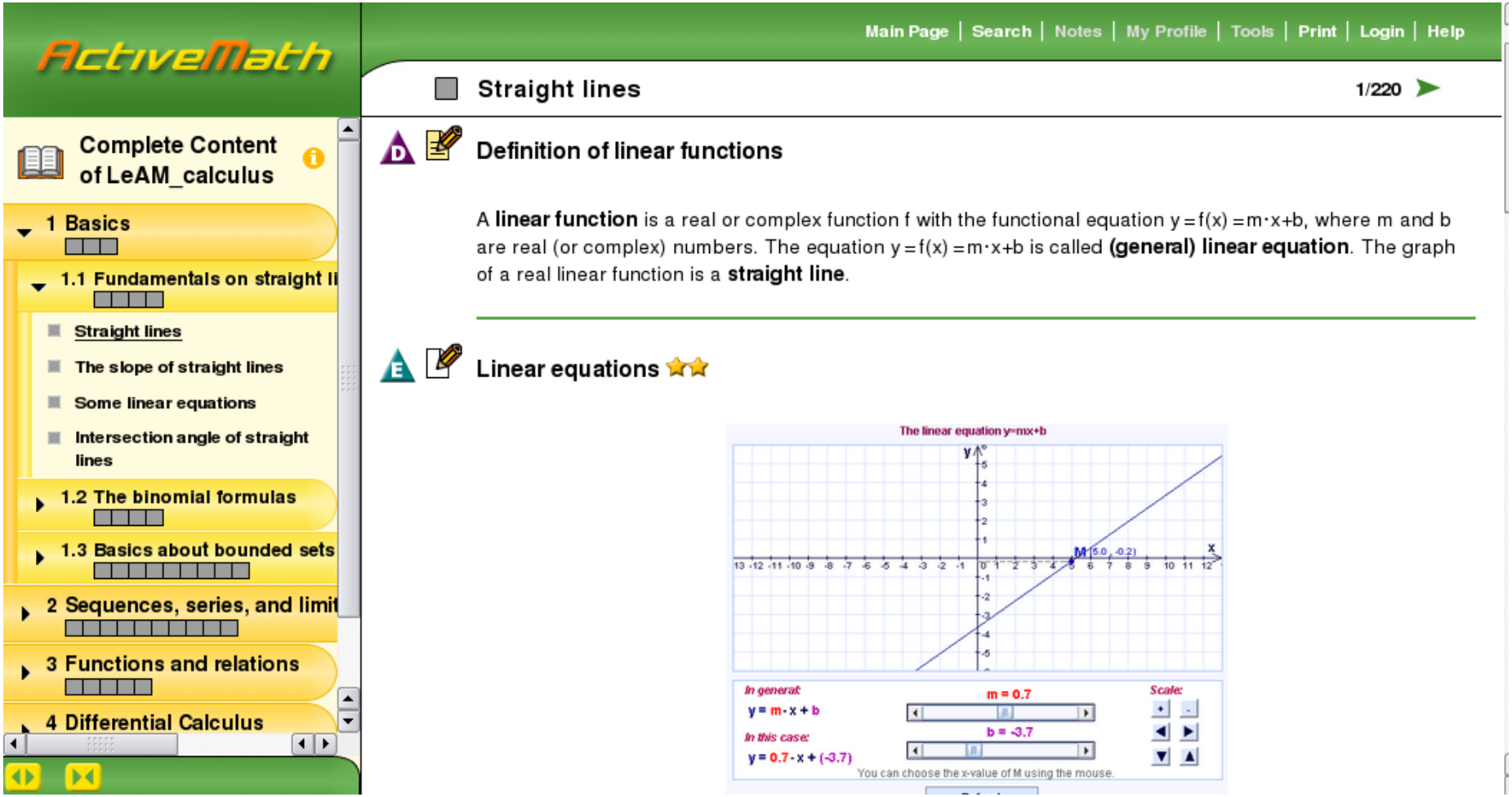
MKM Technologies

- ICT for fully **articulating MK**: mathematical editors; representation formats; markup support
- ICT for **disseminating MK** on the WWW and between computer system
  - Digitalization of mathematical textbooks (OCR technologies)
  - ICT for making MK available on WWW
  - Representing MK for further computations
- ICT for **accessing MK**:
  - tools for search and queries;
  - for performing computations with mathematical software systems,
  - and *for understanding how the knowledge has been articulated and organized*

William Farmer [Far05, Far04]; MKM conferences [Loz03],[BC01]. . . [MKM08], MKM Interest Group [MKM07]

Adaptive MKM Technologies

The LeActiveMath System



Download at http://www.activemath.org/

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Community of Practice (CoP)

- Coined by Jean Lave and Etienne Wenger in the 80s to express the need for a *new theory of learning*.
- CoPs are groups of people who **share an interest** in a particular domain.
- By interacting and collaborating around problems, solutions, and insights they **develop a shared practice**, i.e. a common repertoire of resources consisting of experiences, stories, tools, and ways of addressing recurring problems.
- CoP concept has been applied in many domains such as learning/ education, government, **science**, industry, ect.

Jean Lave and Etienne Wenger [LW91, Wen05b, Wen05a, WMS02]

CoPs in Science

- Frequently change their role between expert and novice
- Many subcommunities that differ in their practice and preference
  - preferred mathematical notations [KMR08, Caj93, SW06, Mül08]
  - different basic assumptions/ foundations [Rab08]
  - usage of specific results and existing work [KW05]
  - choice of typical examples [KMS92, KMS93, KK06]
- Scientists interact via their artifacts
  $\Rightarrow$ Scientific practice is inscribed into artifacts.
- Scientists use various tools to articulate, organize, disseminate, and access artifacts
- No all-embracing solution exists
  $\Rightarrow$ Integration by sharing artifacts and user data

Andrea Kienle and Martin Wessner [KW05, KW, KW06, WK07]

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CoPfolios: Collaborative Models

- CoPfolios can be compared to *SCORM packages in eLearning* that allow integration between different eLearning applications
- **Copfolios** integrate *mathematical artifacts* including *user-specific information and preferences*.
- Technically, CoPfolios are *collection of semantic artifacts* represented in the **Open Mathematical Document Format (OMDoc)**
- **Semantic artifacts** are **semi-formal documents**. The markup of their **structural semantics** allows to distinguish the included *interconnected fragments* as well as to explicate the *inscribe scientific practice and preference*.

Content of CoPfolios

- notation preferences
- *typical examples* for illustrating theories, procedures, or concepts
- papers, preprints,
- emails, forum postings, online reviews, and wiki entries
- discussion items, ratings, tags, and subscriptions
- software and libraries

Basically all artifacts, user data, and preference settings, which can be *reificated*, i.e. represented as an object, and *marked up in OMDoc*.

Semi-Formal Markup with OMDoc

- **OMDoc** is a *markup format and data model* for *Mathematical Documents*.
- It serves as *semantics-oriented representation format* and *ontology language for mathematical knowledge*.
- OMDoc is an extension of the **OpenMath** and (content) **MathML standards** (markup on *object level*).
- It extends these formats by markup for the *document and theory level of mathematical documents*.

OMDoc Portal: http://www.omdoc.org
MathML Interest Group: http://www.w3.org/Math/
OpenMath Interest Group: http://www.openmath.org/

The MathML and OpenMath Standard

Representing Mathematical Objects and their Notations

- **(presentation) MathML** is the *standard for presentation mathematical objects* on the WWW
- **OpenMath** is a *standard for representing mathematical objects*, it is solely concerned with the semantics (meaning) or content of mathematical objects
- Semantics of mathematical concepts is defined in **content dictionaries** (CDs). The *commonly agreed* on definitions and symbols are included in the *public CD collection* at `http://www.openmath.org/`

The MathML and OpenMath Standard

OpenMath Representation

```
<om:OMOBJ>
 <om:OMA>
  <om:OMS cd="combinat1"
          name="binomial" />
  <om:OMV name="n" />
  <om:OMV name="k" />
 </om:OMA>
</om:OMOBJ>
```

MathML Representation

```
<m:mrow>
  <m:mo>(</m:mo>
  <m:mfrac linethickness="0">
    <m:mi>n</m:mi>
    <m:mi>k</m:mi>
  </m:mfrac>
  <m:mo>)</m:mo>
</m:mrow>
```

Displayed as: $\binom{n}{k}$

Content Dictionary “combinat1” defines the symbol “binomial”:
http://www.openmath.org/cd/combinat1.xhtml#binomial

An OMDoc Document

```
<?xml version="1.0" encoding="UTF-8"?>
<omdoc xmlns="http://omdoc.org/ns" ...>
  <notation>
    ...
  </notation>
  <theory xml:id="MyTheory">
    <imports from="http://www.openmath.org/cd/combinat1.xhtml#binomial" />
    <omtext xml:id="id2">
      <CMP>
        The binomial coefficients is the number of ways of choosing
        m objects from a collection of n distinct objects
        without regard to the order. We denote it by
        <om:OMOBJ><om:OMA>
          <om:OMS cd="combinat1" name="binomial" />
          <om:OMV name="n" />
          <om:OMV name="k" />
        </om:OMA></om:OMOBJ>.
      </CMP>
    </omtext>
  </theory>
</omdoc>
```

Explicating Notation Preferences in OMDoc

Notation Definition of Binomial Coefficient:

```
<notation
  xmlns:m="http://www.w3.org/1998/Math/MathML"
  xmlns:om="http://www.openmath.org/OpenMath"
  cdbase="http://www.openmath.org/cd"
  cd="combinat1" name="binomial">
  <prototype>
    <om:OMA>
      <om:OMS cd="combinat1" name="binomial" />
      <expr name="arg1"/>
      <expr name="arg2"/>
    </om:OMA>
  </prototype>
  ...
```

Rendered:

$\binom{n}{k}$ (German)

C_k^n (Russian)

C_n^k (French)

```
  ...
  <rendering context="language:German,de">
    <m:mrow>
      <m:mo>(</m:mo>
      <m:mfrac linethickness="0">
        <render name="arg1"/>
        <render name="arg2"/>
      </m:mfrac>
      <m:mo>)</m:mo>
    </m:mrow>
  </rendering>
  <rendering context="language:Russian,ru">
    <m:msubsup>
      <m:mi>C</m:mi>
      <render name="arg1"/>
      <render name="arg2"/>
    </m:msubsup>
  </rendering>
  <rendering context="language:French,fr">
    <m:msubsup>
      <m:mi>C</m:mi>
      <render name="arg2"/>
      <render name="arg1"/>
    </m:msubsup>
  </rendering>
</notation>
```

An Example CoPfolio

Theories & Basic Assumptions

```
<?xml version="1.0" encoding="UTF-8"?>
<omdoc xmlns="http://omdoc.org/ns" ...>
  ...
  <theory xml:id="MyTheory">
    <imports from="http://www.openmath.org/cd/
             combinat1.xhtml#binomial" />
    <omtext xml:id="id2">
      <CMP>
        The binomial coefficients is the number of ways
        of choosing m objects from a collection of n
        distinct objects without regard to the order.
        We denote it by
        <om:OMOBJ><om:OMA>
          <om:OMS cd="combinat1" name="binomial" />
          <om:OMV name="n" />
          <om:OMV name="k" />
        </om:OMA></om:OMOBJ>.
      </CMP>
    </omtext>
  </theory>
  ...
</omdoc>
```

Notation Preferences

```
<notations>
  ...
  <notation>
    <prototype>
      <om:OMA>
        <om:OMS cd="combinat1" name="binomial" />
        <expr name="arg1" /><expr name="arg2" />
      </om:OMA>
    </prototype>
    <rendering context="language: German, de">
      <m:mrow><m:mo>(</m:mo>
        <m:mfrac linethickness="0">
        <render name="arg1" /><render name="arg2" />
        </m:mfrac>
      <m:mo>)</m:mo></m:mrow>
    </rendering>
  </notation>
  ...
</notations>
```

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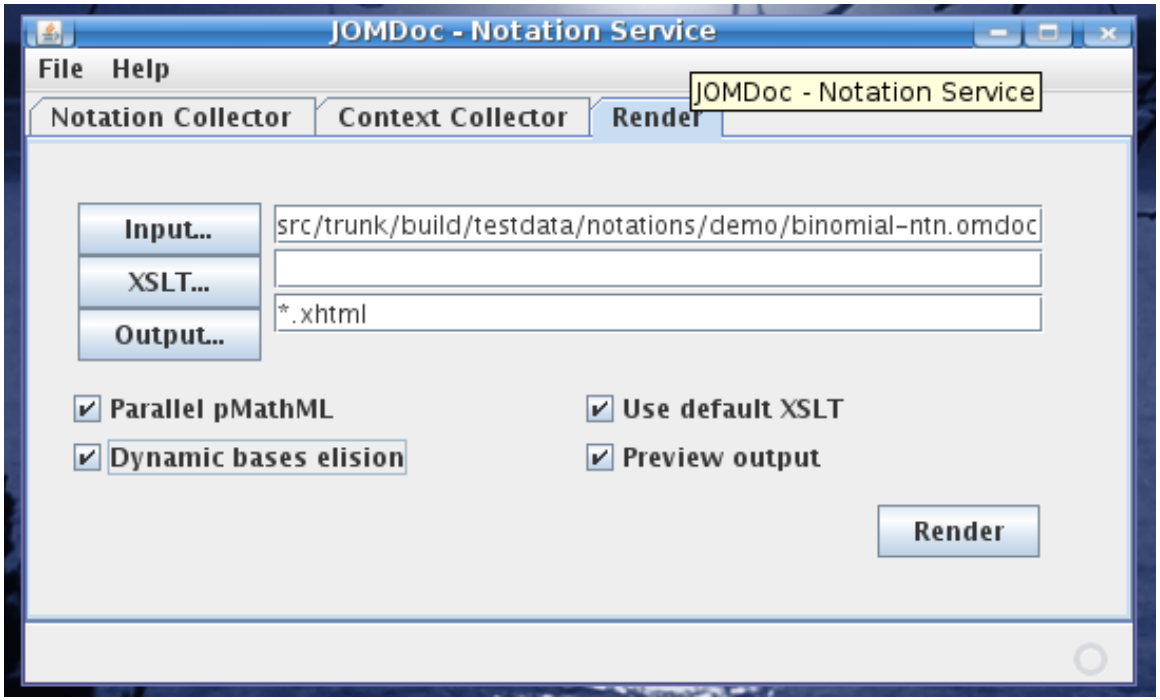
CoPit: A toolkit for Managing CoPfolios

CoPit consists of three main components:

- **JOMDoc:** A library for *manipulating OMDoc Documents*
  http://omdoc.org/jomdoc
- **OMBase:** A repository for *storing OMDoc Documents*
  http://kwarc.info/projects/ombase
- **JOBAD:** A Javascript Framework for web-based system to provide *interactive displays of OMDoc Documents* on the WWW
  https://trac.kwarc.info/jomdoc

JOMDoc: A Java library for OMDoc Documents

JOMDoc provides a GUI and commandline client.



⇒ Download at http://omdoc.org/jomdoc

⇒ Contact me for a demo

JavaScript Framework for active documents

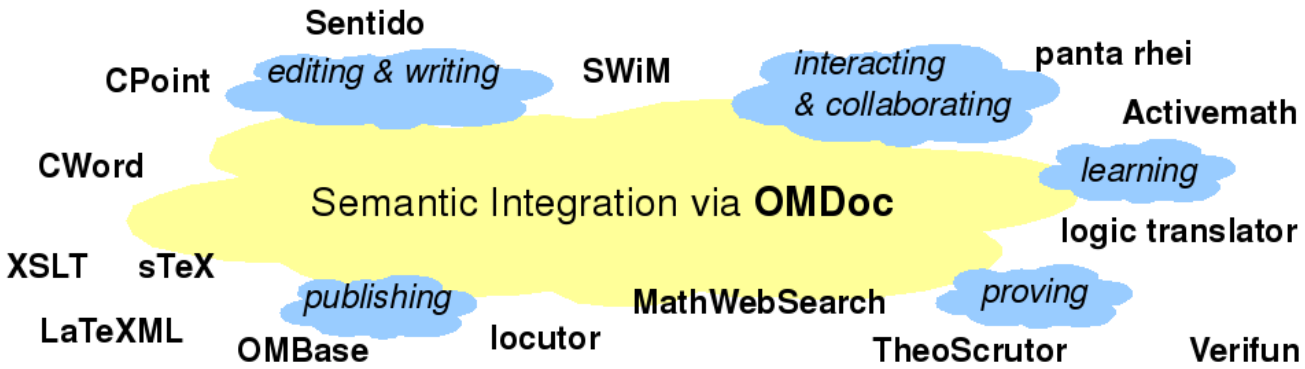
Active documents are documents in a browser that *provide semantic services* based on the semantics inside the document

- Folding of formula e.g. $(a/b) + (a/c) \Rightarrow ... + ...$
- Interlinking of symbols and their definitions
- Providing a guided tour to explain a given formula. The tour provides all definitions and explanations of symbols in the formula.
- Search for the document's formula in the WWW
- Unfolding of formula based on definition: e.g. $3! \Rightarrow 1 * 2 * 3$
- Changing notations
- Flexible elisions
- Proving mathematical statements

Integrating CoPit with the OMDoc Universe

Systems that support OMDoc can

- Integrate JOMDoc to manipulate OMDoc Documents
- Integrate OMBase for storing OMDoc Documents
- Integrate JOBAD to provide interactive display of OMDoc Documents



CoPfolios are used to exchange artifacts and user preference between these systems. They can be interpret and handle by making use of the CoPit components.

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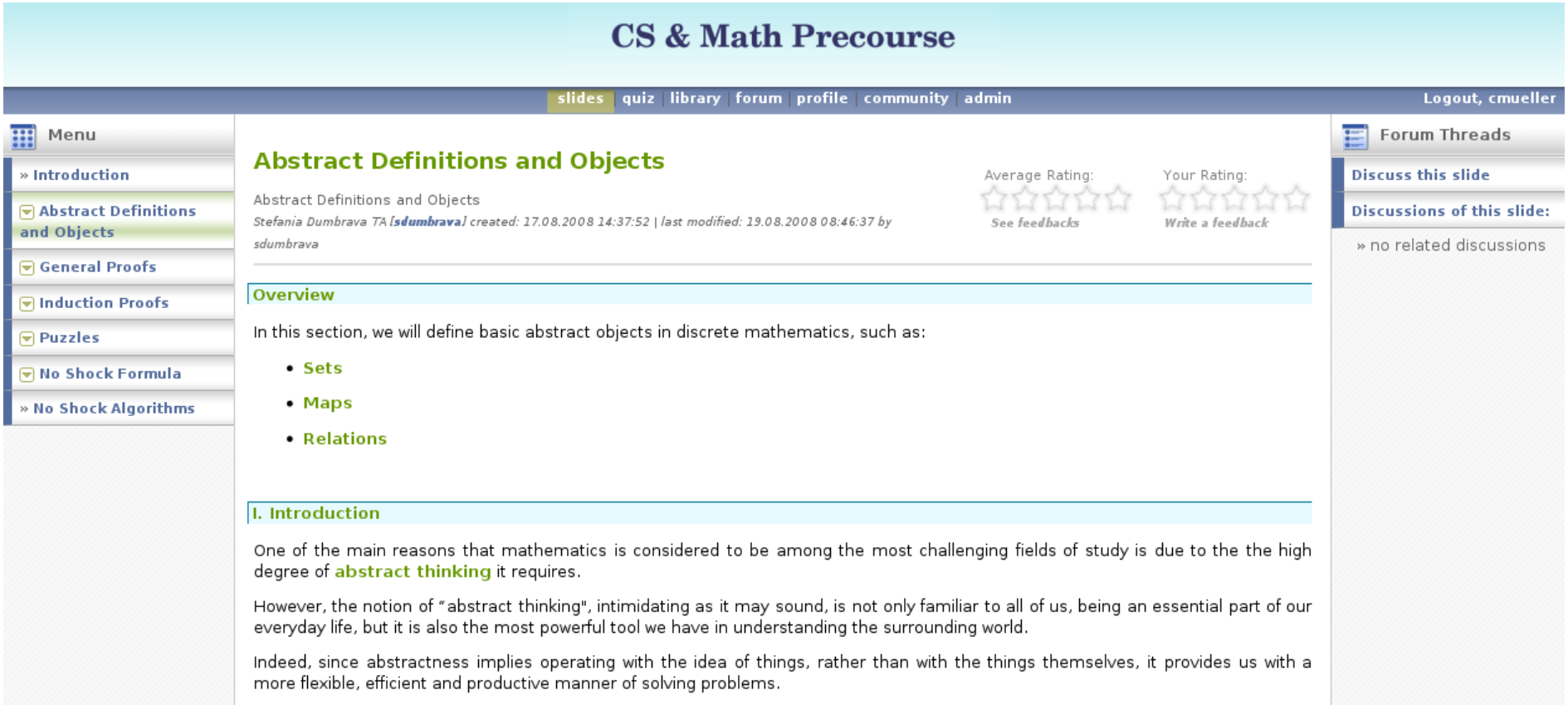
Case Study

- The panta rhei system is currently used within our Freshmen Computer Science lecture to allow students *to discuss, rate, and access our course material*.
- Panta rhei *integrates JOMDoc to adapt the notations* of the course wrt. to a user's preference setting.
- It will soon *integrate JOBAD to allow students to interact with the course material*, e.g. to change the presented notations on the fly.
- Panta rhei uses its own database to manage its OMDoc material. Soon it will be integrated with OMBase.

Panta Rhei



See panta rhei website at http://kwarc.info/projects/panta-rhei

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Outlook & Conclusion

- Mathematicians use many tools, no all-embracing solutions, no *sharing of content and user data*
- **CoPfolios** as collection of semantic artifacts and user-specific information
- **CoPit** for managing CoPfolios using *JOMDoc, OMBase, JOBAD*

Current Focus:

- Development of the CoPit components
- Evaluation with panta rhei
- Extending OMDoc to explicate further practice:
  Reificating the *choice of typical examples and exercises*.

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