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DESIGNING TEXTBOOKS WITH ENHANCED FEATURES TO INCREASE STUDENT INTERACTION AND PROMOTE INSTRUCTIONAL CHANGE

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UNIVERSITY OF MICHIGAN

American Institute of Mathematics

Est. 1888 UNIVERSITY of PUGET SOUND

SFA

University of Colorado

PLAN OF TALK

- Research space: rationale, open source/open access textbooks, research questions
- Study design: Theoretical framing, research design, and data collection
- Findings: Instructor and Student use
- Next steps

RATIONALE

Free, open source, dynamic textbooks for university mathematics courses are now everywhere available for students and instructors

Particularly important for calculus:

- It has a ”stable” curriculum
- Gateway course for other fields→ large enrolment
- Amenable to seamless integration with technology

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RATIONALE

This can be seen as great news for teaching and learning of calculus…

Are the enhanced features increasing interaction with ideas, the textbook, other students, the instructor?

- How are open source/open access textbooks used by teachers?
- How are they used by students?
- How can they be used promote instructional change?

CURRENT APPROACHES

- One-to-one observations and interview studies → how much students understand (e.g., Sierpinska,1997)
- Survey studies → activities students say they do: "prepare for exams" (e.g., Weinberg, *et al*. 2012)
- Data analytics → clustering of students by usage behavior (e.g. Philips, *et al*. 2010)

OUR APPROACH

Exploratory, mixed methods study to investigate instructor and student uses of three open source textbooks:

- Active Calculus, Boelkins (https://activecalculus.org/)
- First Course in Linear Algebra, Beezer (http://linear.ups.edu/)
- Abstract Algebra: Theory and Applications, Judson (http://abstract.ups.edu/)

OPEN SOURCE OPEN ACCESS TEXTBOOKS

- Open source: The source file(s) are freely available for others to download and use.
- Open access: When only a PDF or other digital format is freely available and printable

  An electronic version that cannot be printed **is not** open access.

We use the expression “open textbook” to mean either open source or open access.

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AUTHORED IN PRETEXT…

- No proprietary interfaces
- Compact and portable
- Accessible from any device—laptop, tablet, phone
- Current: edit and refresh at will, never out-of-print
- Crowd-sourced proof-reading
- No pressure to satisfy market segments
- Many output formats
- **FREE!**

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THEORETICAL FRAMEWORKS

Vygotsky's Subject-Tool-Object

↓

Rabardel's
Duality of Instruments

↓

Instrument= Artifact + Scheme of use

↓

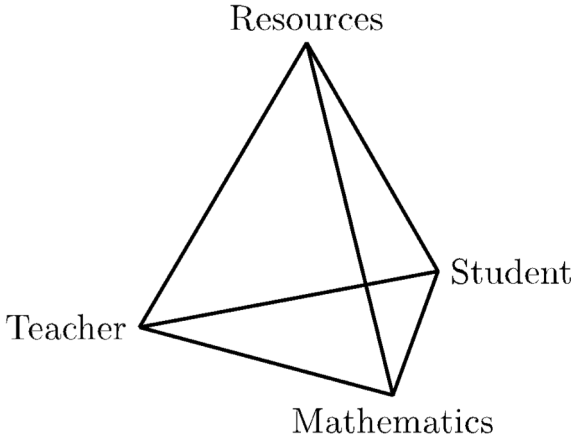
Documentational Approach

Document: Resources + Schemes of Use.

Resources: A collection of artifacts gathered for a specific purpose/class of situations.

Schemes of Use: Uses (rules of action) + Operational Invariants (when those rules are called for and why)

Rezat's didactical tetrahedron



(Gueudet & Trouche, 2009; Rabardel & Wearn, 2003; Rezat 2012)

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TEXTBOOK FEATURES

- Motivating questions
- Preview activities
- “Explanation” text with elaboration, definitions, theorems, demonstrations, commentary, invitations to explore (http://gvsu.edu/s/5C http://gvsu.edu/s/5D)
- Activities
- Summary
- Exercises and problems

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DESIGN

- Concurrent mixed methods
- 15 instructors, 432 students, 10 states

Format	Textbook	Course	Instructor	# of Students
HTML	Judson	Abstract Algebra	**T3**	12
			T5	**27 (2nd term)**, 22 (3rd term)
	Boelkins	Active Calculus	T16	11
	Beezer	Linear Algebra	**T1**	29
			T11	26
			T12	29
			T17	20
			T18	28
			T4	12
			T8	**22 (2nd term)**, 29 (3rd term)
			T9	23
PDF/Hardcopy	Judson	Abstract Algebra	**T7**	19
	Boelkins	Active Calculus	T13	16
	Beezer	Linear Algebra	**T15**	70
	Strang	Abstract Algebra	**T2**	37

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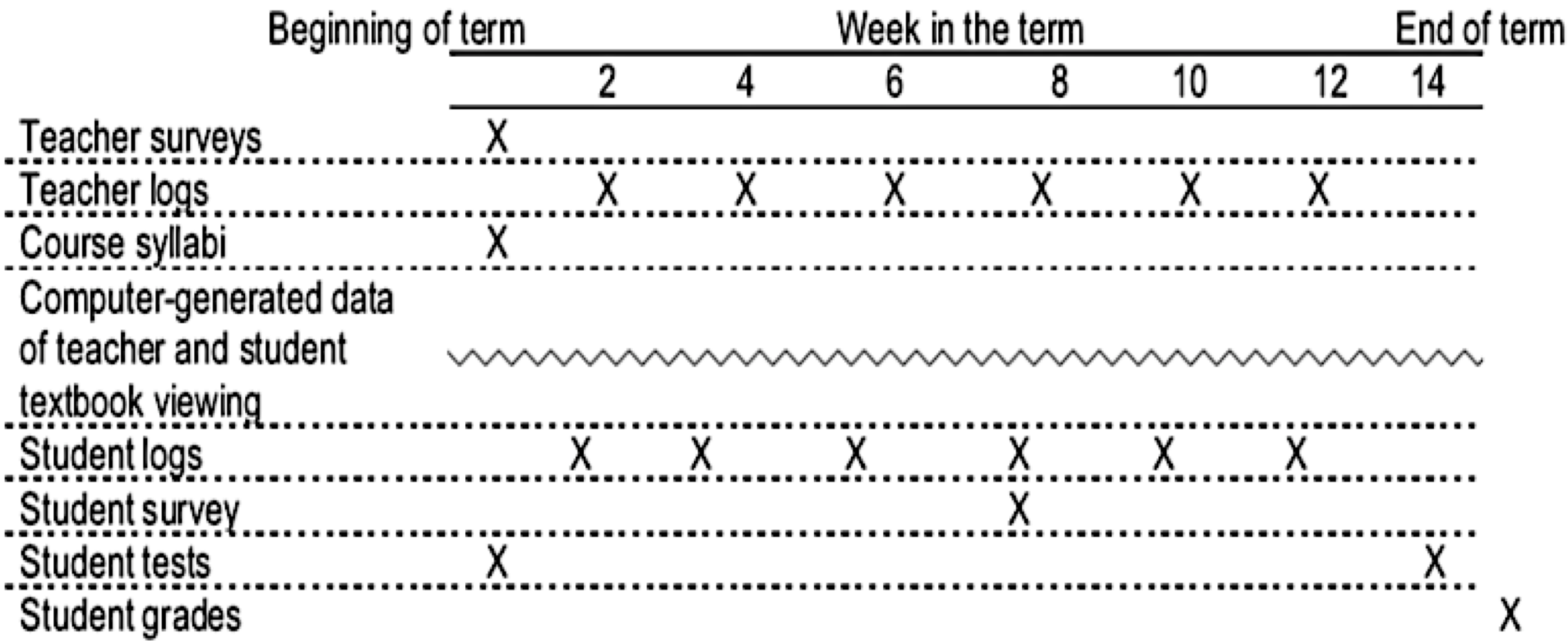
DATA COLLECTION



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“HEATMAPS”

- Representation of viewing data by section, time, user

  https://books.aimath.org/tracktest/

- Gives a sense of textbook viewing—tangentially of use
- Augmented with user log information

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PRELIMINARY RESULTS
(FIRST WAVE, CALCULUS ~24 students)

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INSTRUCTORS' USE OF TEXTBOOK

- Most features implemented as anticipated
  - Before class: Motivation questions + pre-activities
  - During class: Activities
- Not much use of "reading questions"
- Details of tracked use…

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INSTRUCTORS' USE OF TEXTBOOK

- **Instructor 431016:** "Goals of the class: Concavity, 2nd derivative test, basics of curve sketching. On the previous class, I had assigned the students to do Preview Activity 3.1.1, Activity 3.1.2, and one problem not in the book. Lesson planning: First, I used the book to recall what I'd assigned, because the first 10 minutes of class is spent with the students presenting answers to the homework. (From 7:55 - 8:05 PCT, according to the heat map.)

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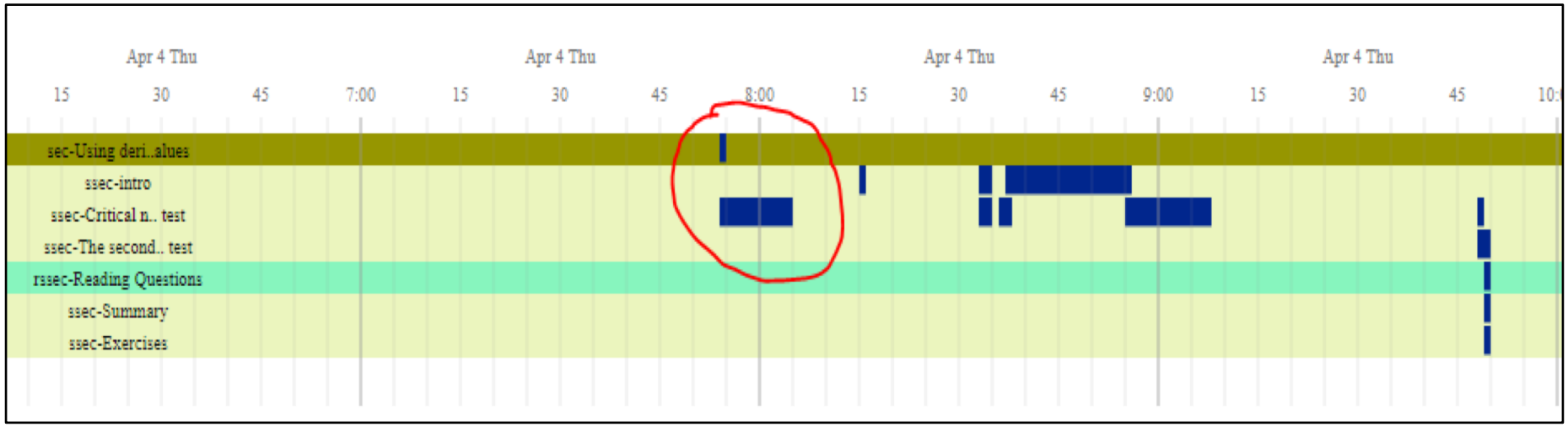

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STUDENTS' USE OF TEXTBOOKS

Out of class:

- Majority mostly use examples and solutions
- Re-read text when something is unclear
- Create personal notes augmented with textbook information, pictures, activities worked in class, assignments
- Consult other sources (Wolfram alpha, Google, peers, tutors, their instructors, Khan Academy)

In class:

- "reading questions" & activities in groups

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STUDENTS' USE OF TEXTBOOKS

Feature	Use
Activities	Answer homework questions, workout what was done in class, apply theorems/definitions
Definition	Understand concepts, read to figure out how to solve homework & other problems
Examples	Answer homework questions, workout theory taught in class, construct solutions to key examples
Exercises	Workout theory taught in class, Answer homework questions
Preview Activities	Be better prepared for the upcoming class, checkout how textbook definitions are used

STUDENTS' USE OF TEXTBOOK

- **Student 43101607 (Feb 27th, the most squares in a day):** "I opened the textbook and went to section 1.7 and skipped through until I got to the exercises, which were assigned for homework. Once I had copied the problem and found what I thought was the correct answer for the assigned problem, I looked at the solution and if I got any questions wrong I made sure I understood where I made my mistake and corrected it."

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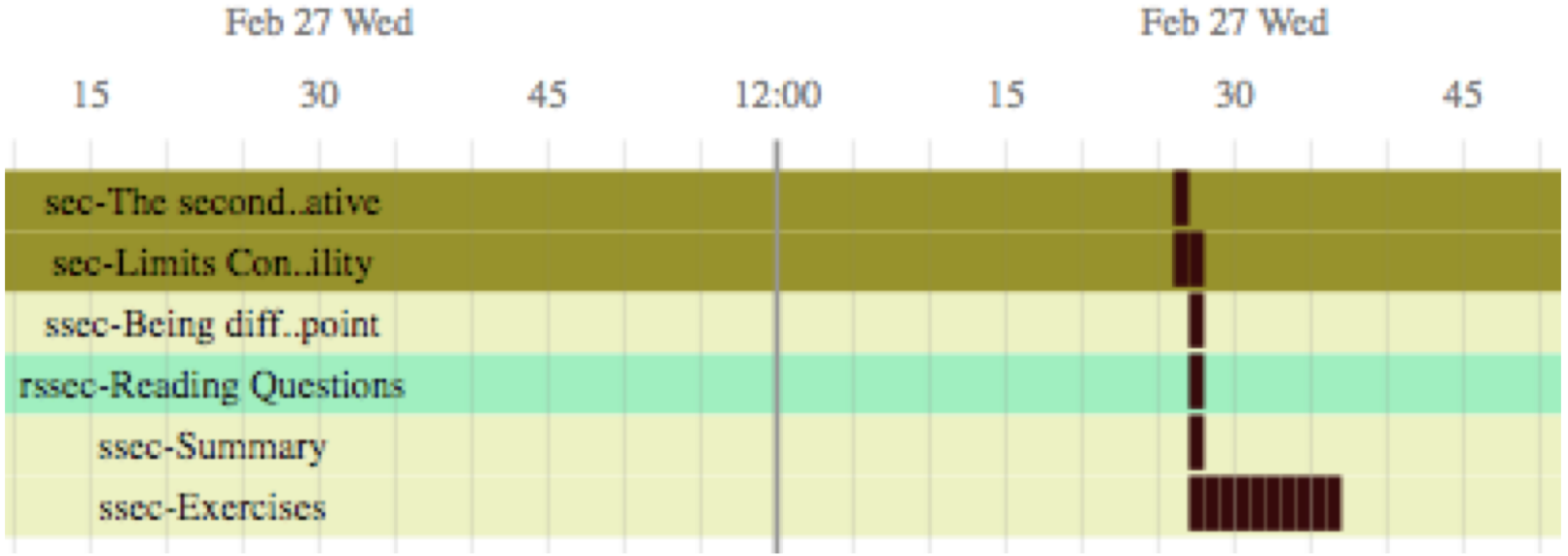

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STUDENTS' PERFORMANCE

- Statistically significant gain from beginning to end of term test in both sections (an average of 29% gain)
  - Items with large gains: sketching graph of derivative from a graph; explaining why graphs can't represent a particular value of $f'(x)$
  - Items with small/no gains: value of limit, interpreting inverse function of a value, estimating change in volume and FTC
- No correlation with grades

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NEXT STEPS

1. Improving the viewing data representation and mining and better connecting those with users' responses to their use (lag time)
2. Refining algorithms for natural language processing to identify patterns of responses to log questions
3. Collecting better data from users' mathematical interactions via reading questions to describe understanding
4. Tracing instrumentation & instrumentalization processes
5. How are the interactions in the classroom?

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UNDERGRADUATE TEACHING (AND LEARNING) IN MATHEMATICS WITH OPEN SOFTWARE AND TEXTBOOKS

THANK YOU!

Collaborators:

Rob Beezer	University of Puget Sound
David Farmer	American Institute of Mathematics
Tom Judson	Stephen F Austin State U
Susan Lynds	University of Colorado at Boulder
Yannis Liakos	University of Michigan-Ann Arbor
Kent Morrison	American Institute of Mathematics

utmost.aimath.org

mathbook.pugetsound.edu

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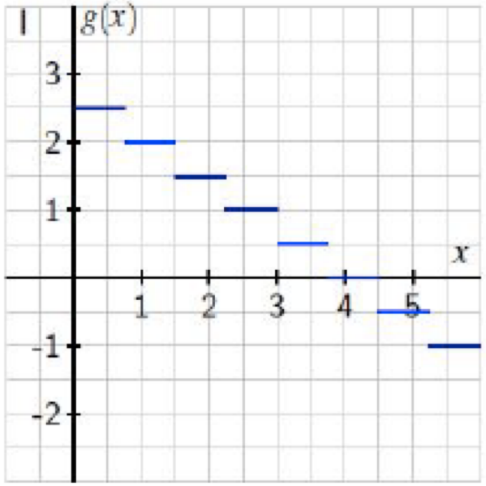
ITEM

3. There is a function g for which $g'(3) = 0$. Explain why none of the graphs shown below could be the displayed graphs of g.

I



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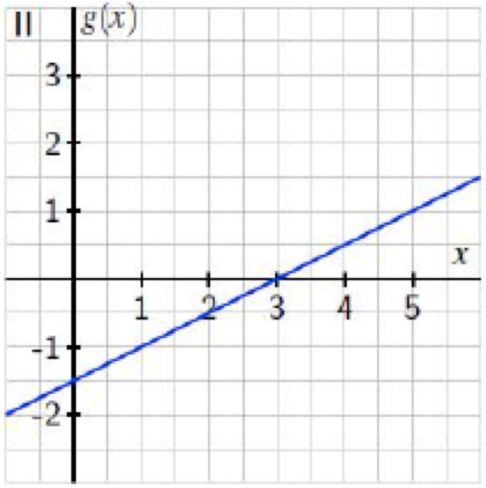

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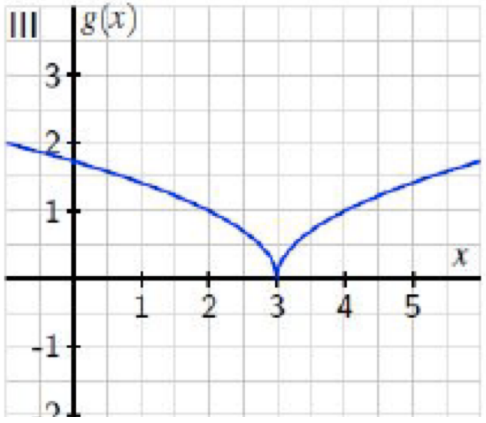

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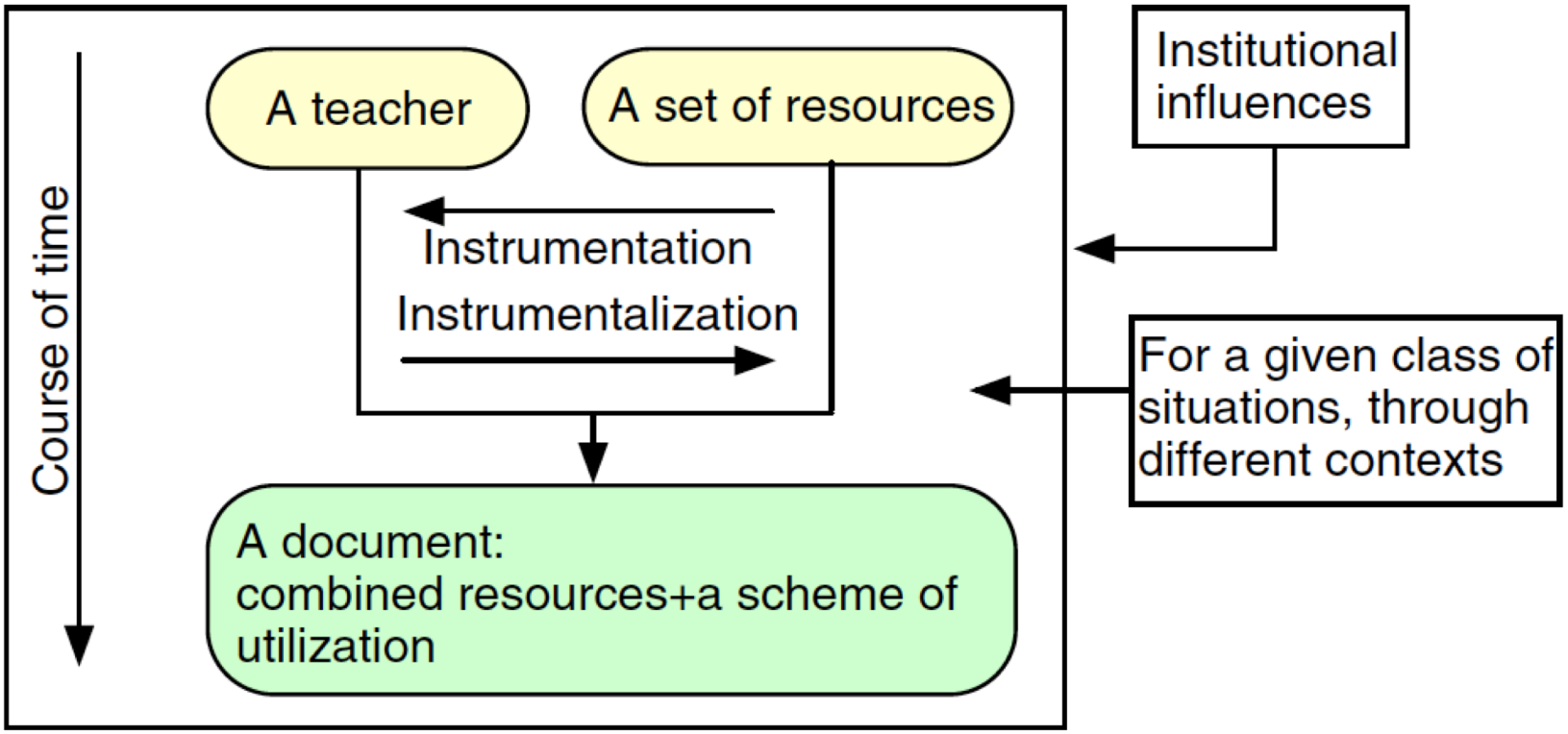
DOCUMENTATIONAL APPROACH



Instrumentalization: the teacher/user shapes the set of resources by using them

Instrumentation: the affordances and constraints of the set of resources influences the teacher/user

(Gueudet & Trouche, 2009; Rabardel & Waern, 2003)

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