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4º Seminario Investigacion + Aprendizaje

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UNDERGRADUATE TEACHING (AND LEARNING) OF MATHEMATICS WITH OPEN SOURCE TEXTBOOKS

SCHOOL OF EDUCATION
UNIVERSITY OF MICHIGAN

American Institute of Mathematics

UNIVERSITY of PUGET SOUND

University of Colorado

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.

EDUCATION

ADVANTAGES OF OPEN TEXTBOOKS

- 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!**

EDUCATION

THE PROBLEM

What is the potential of open textbooks to improve mathematics teaching and learning?

- 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 (e.g. Philips, et al 2010)

ADDRESSING THE PROBLEM

Exploratory study to investigate instructor and student uses of two open source textbooks:

First Course in Linear Algebra by Rob Beezer

Abstract Algebra: Theory and Applications by Tom Judson

- How do instructors use the textbooks?
- How do students use the textbooks?
- Are there differences in use between dynamic and PDF formats?

THEORETICAL FRAMEWORKS

Vygotsky's Subject-Tool-Object

↓

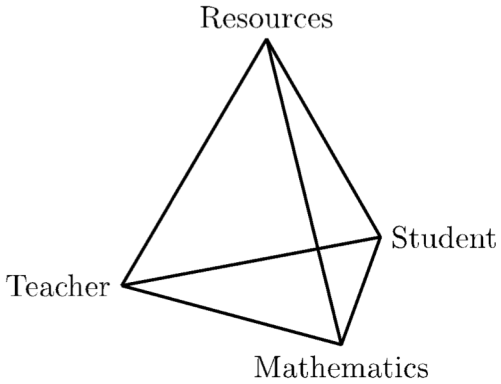
Rabardel's
Duality of Instruments

↓

Documentational Approach

Rezat's didactical tetrahedron

Instrument= Artifact + Scheme of use



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)

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

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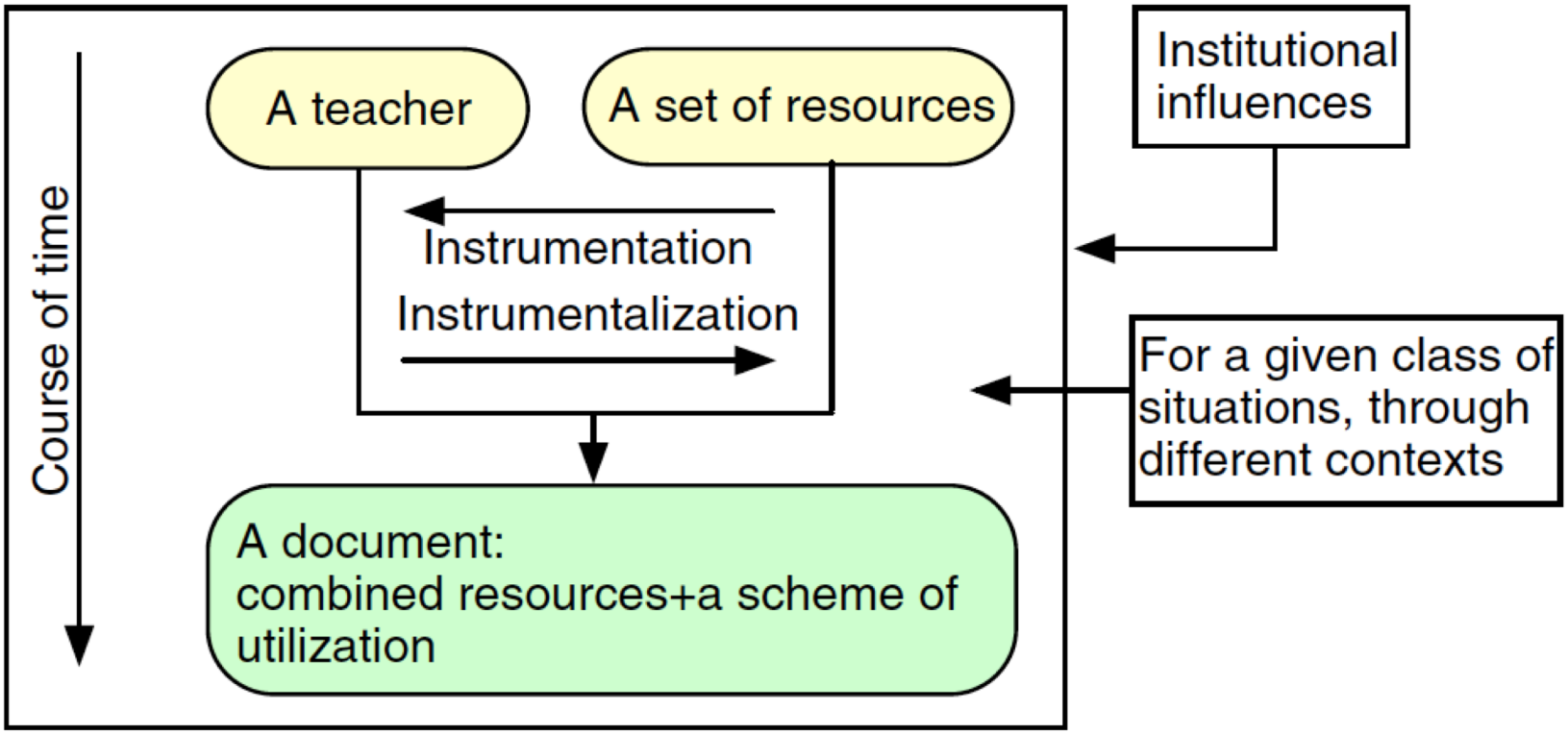
DOCUMENTATIONAL APPROACH



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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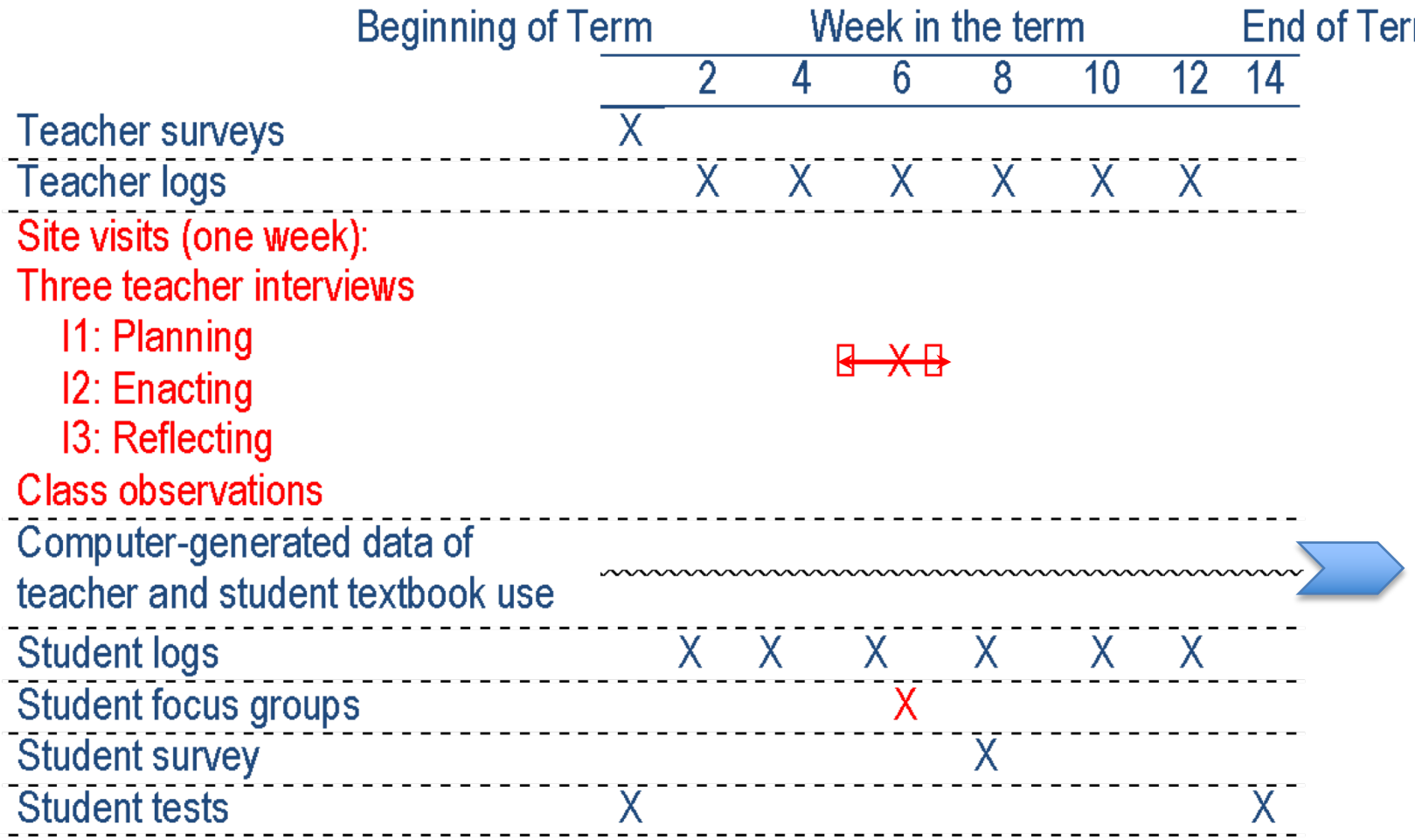
DESIGN

- Mixed methods (concurrent)
- 11 instructors + students, 10 institutions, 7 states

Format	Textbook	Course	Instructor	# of Students
HTML	Beezer	Linear Algebra	**T1**	29
			T4	12
			T8	**22 (2nd term)**, 29 (3rd term)
			T9	23
			T11	26
			T12	29
	Judson	Abstract Algebra	**T3**	12
			T5	**27 (2nd term)**, 22 (3rd term)
PDF/Hardcopy	Judson	Abstract Algebra	**T7**	19
	Beezer	Linear Algebra	T10	14
Hardcopy	Strang	Abstract Algebra	**T2**	37

DATA COLLECTION PLAN

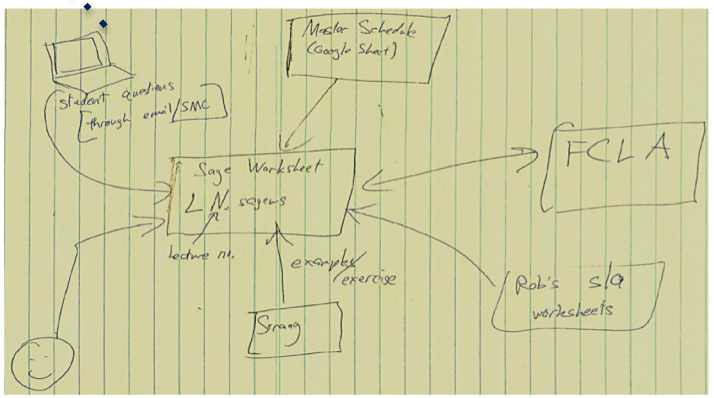


EDUCATION

INSTRUCTORS CREATE LECTURE NOTES…

An instructor

A set of resources

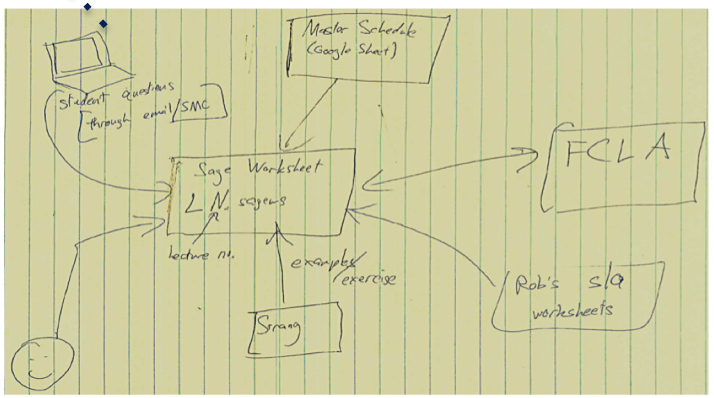


EDUCATION

INSTRUCTORS CREATE LECTURE NOTES…

An instructor ⟷ A set of resources

"The geometric interpretation in $\mathbb{R}^3$ with more than two vectors linearly dependent better reveals the concept of linear dependence [than the technical definition of linear combinations being zero.]"



EDUCATION

INSTRUCTORS CREATE LECTURE NOTES…

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

An instructor → A set of resources

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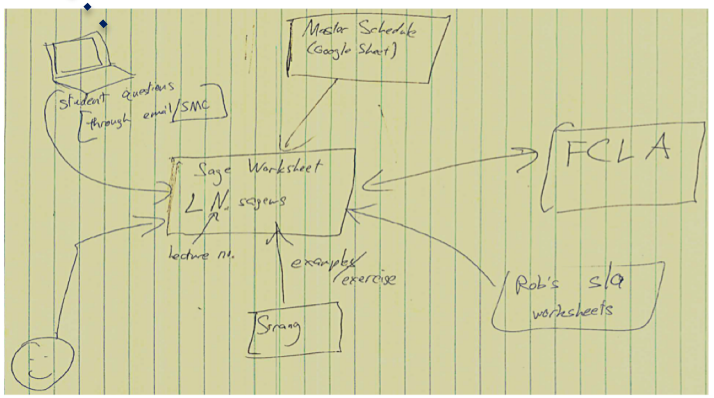

EDUCATION

INSTRUCTORS CREATE LECTURE NOTES…

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

An instructor

A set of resources

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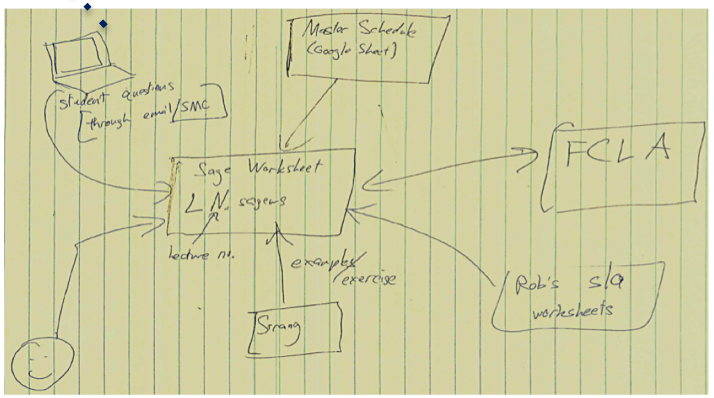

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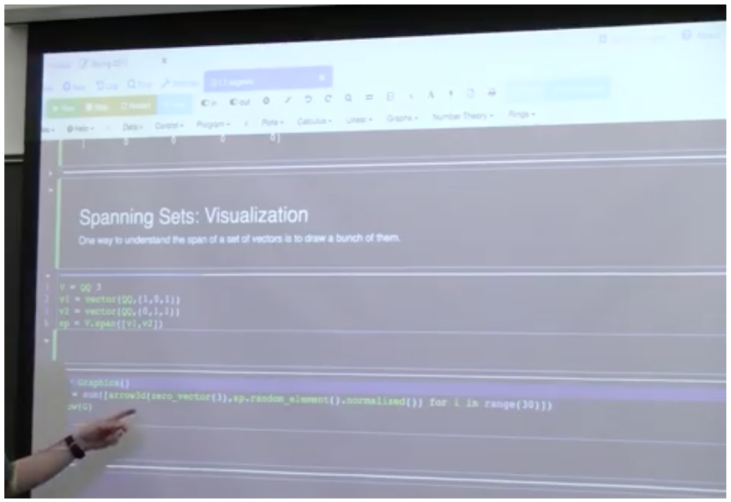
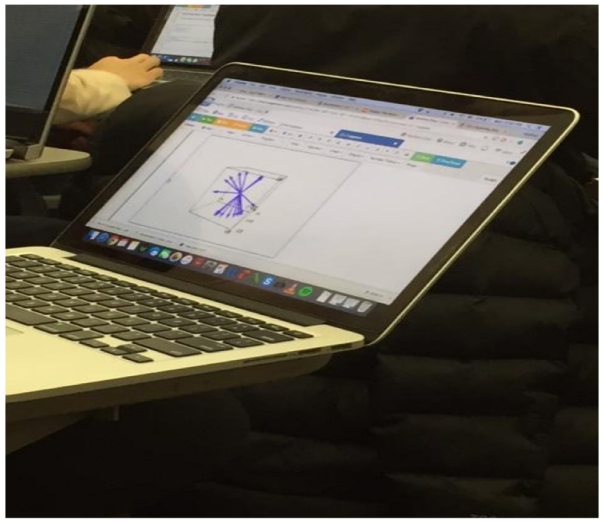
INSTRUCTORS CREATE LECTURE NOTES…

Lecture notes embedded in Sage worksheet and simultaneous student work.





An instructor

A set of resources

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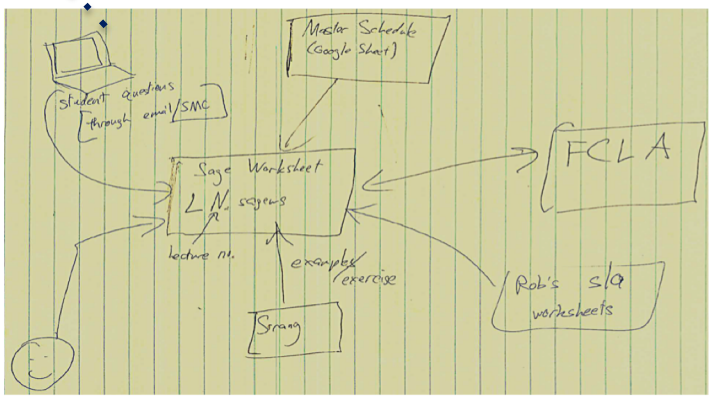
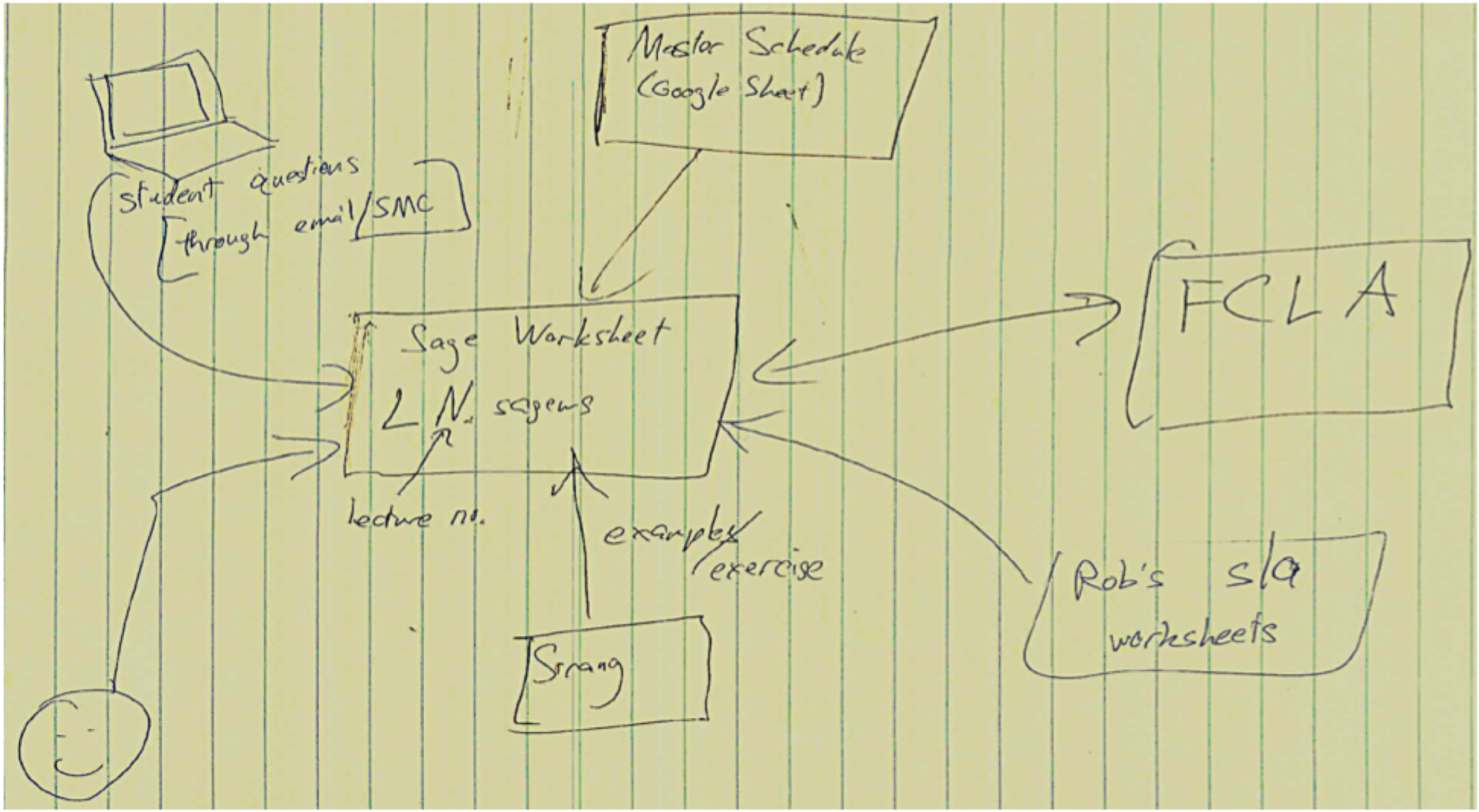


EDUCATION


Master Schedule
(Google Sheet)
student questions
through email/SMC
Sage Worksheet
L N. sagews
FCLA
lecture no.
example/exercise
Rob's s/a
worksheets
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INSTRUCTORS CREATE LECTURE NOTES…

Less to More Dynamic

Lecture Notes	Connection to the Textbook
Handwritten notes in paper (from points of reference to full notes)	References to the textbook
Online videos using the textbook	• Whole parts of the textbook • Practice problems from the textbook in accompanying problem sheets
Beamer/Power Point presentations	Hyperlinks to the textbook
Sage worksheets	• Hyperlinks to the textbook • Capabilities for the production of graphs and calculations of the textbook

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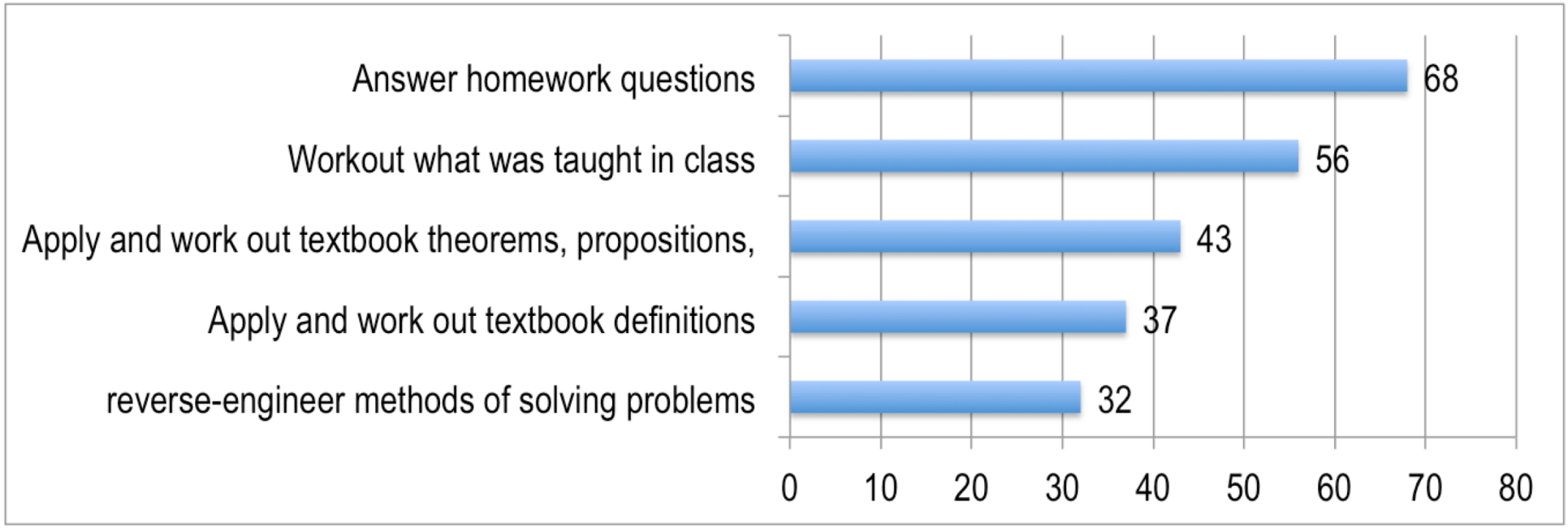
STUDENTS USE THEIR TEXTBOOK

How much do you use… (*N* = 103)

	Scale of Use		
Textbook Elements	**A great deal or A lot**	**Moderate**	**A little or Not at all**
Practice Problems	**67%**	21%	11%
Examples	65%	19%	17%
Solutions	**56%**	25%	19%
Exposition	55%	24%	21%
Definitions	40%	36%	24%
Theorems	31%	36%	34%
Proofs	13%	36%	50%
Propositions, properties, corollaries	12%	35%	52%

STUDENTS USE THEIR TEXTBOOK…

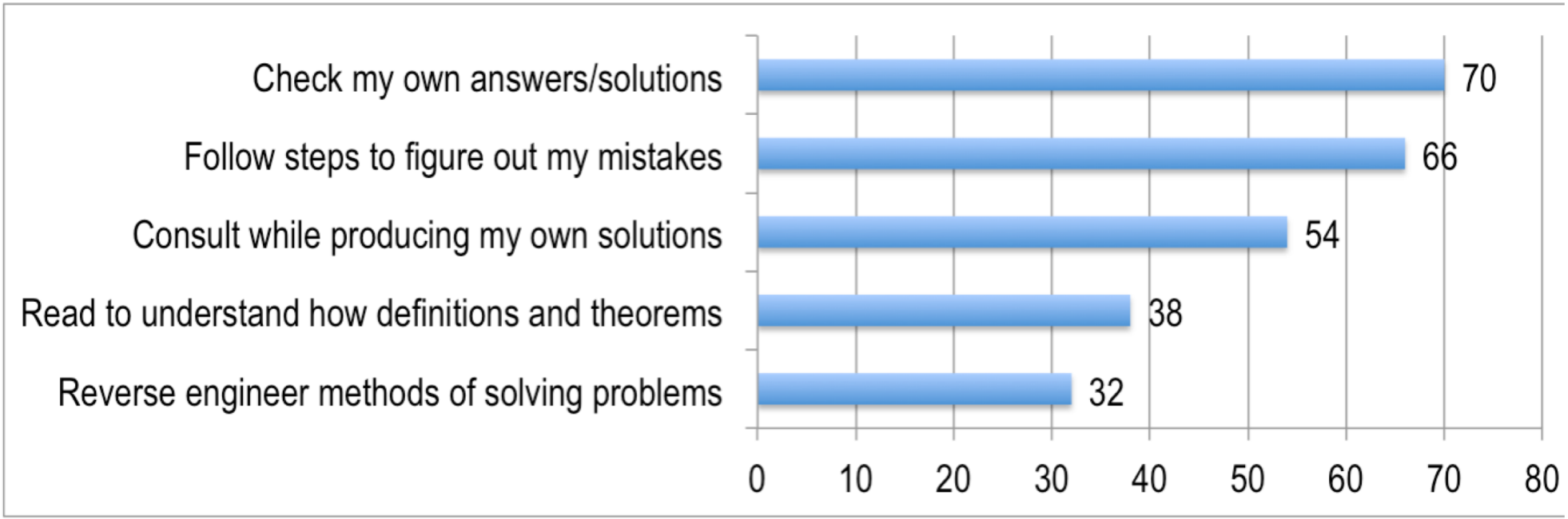
"I **use the practice problems** of the textbook to…
(N = 103)



EDUCATION

STUDENTS USE THEIR TEXTBOOK…

"I **use the solutions** of the textbook to…
(N = 103)



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INSTRUMENTATION: TEXTBOOK + SCHEMES OF USE

	Rules of Action	When/Why
Students	"Read"	Study for examinations/class (study notes)
	Look for definitions	Clarify meaning to work out homework (homework solution)
	Study examples/proofs	Work out the homework (homework solution)
Instructor	Identify major course topics	Create syllabus before the term starts
	Identify theorems and definitions	Create lecture notes to be consistent
	Identify examples	Clarify definitions/theorems in class (lecture notes) Visualize definitions (lecture notes)

CONCLUSIONS: INSTRUCTOR USES OF OPEN TEXTBOOKS

- Use according to…
  - perceptions of teaching and learning at university level (Pepin & Haggarty, 2001)
  - knowledge of availability of, and familiarity with, dynamic features
  - When features can be seamlessly integrated into their usual practices
- Attention to sequencing of topics in the textbook
- Keep notation, definitions, and theorems (no exploration of openness of textbook)

CONCLUSIONS: STUDENT USES OF OPEN TEXTBOOKS

- Most frequently reported using practice problems, examples, and solutions of their textbooks

  (Weinberg, Wiesner, Benesh, & Boester, 2012)

- For homework or for test preparation

  (Anastasakis, Robinson, & Lerman, 2017; Gueudet & Pepin, 2018)

  - Abstract algebra: greater use of theorems and proofs; pre/re-reading and multitasking
  - Linear algebra: examples, practice problems, solutions; taking notes, skimming, or not using the textbook

Next Steps

1. Adding an intervention component
   - workshop in summer on using features of the open textbooks:
     - open source
     - knowls
     - Sage programming
   - pre-workshop measures vs. post-workshop measures
2. Adding a calculus course with WeBWork

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
Angeliki Mali	University of Michigan-Ann Arbor
Kent Morrison	American Institute of Mathematics

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mathbook.pugetsound.edu

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EDUCATION

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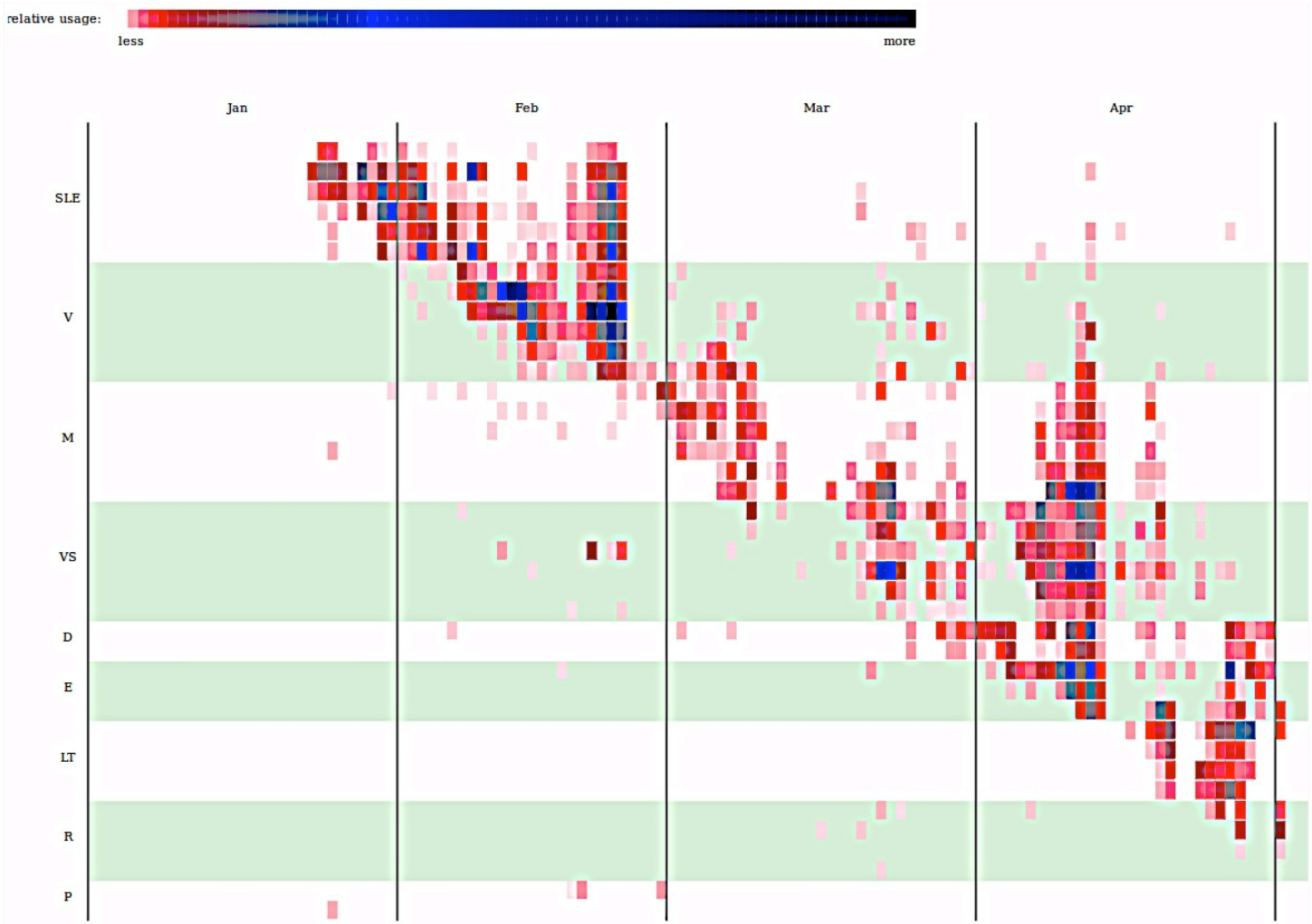
TEXTBOOK USE: ALL USERS, ENTIRE SEMESTER

ROWS ARE SECTIONS, COLUMNS ARE DAYS



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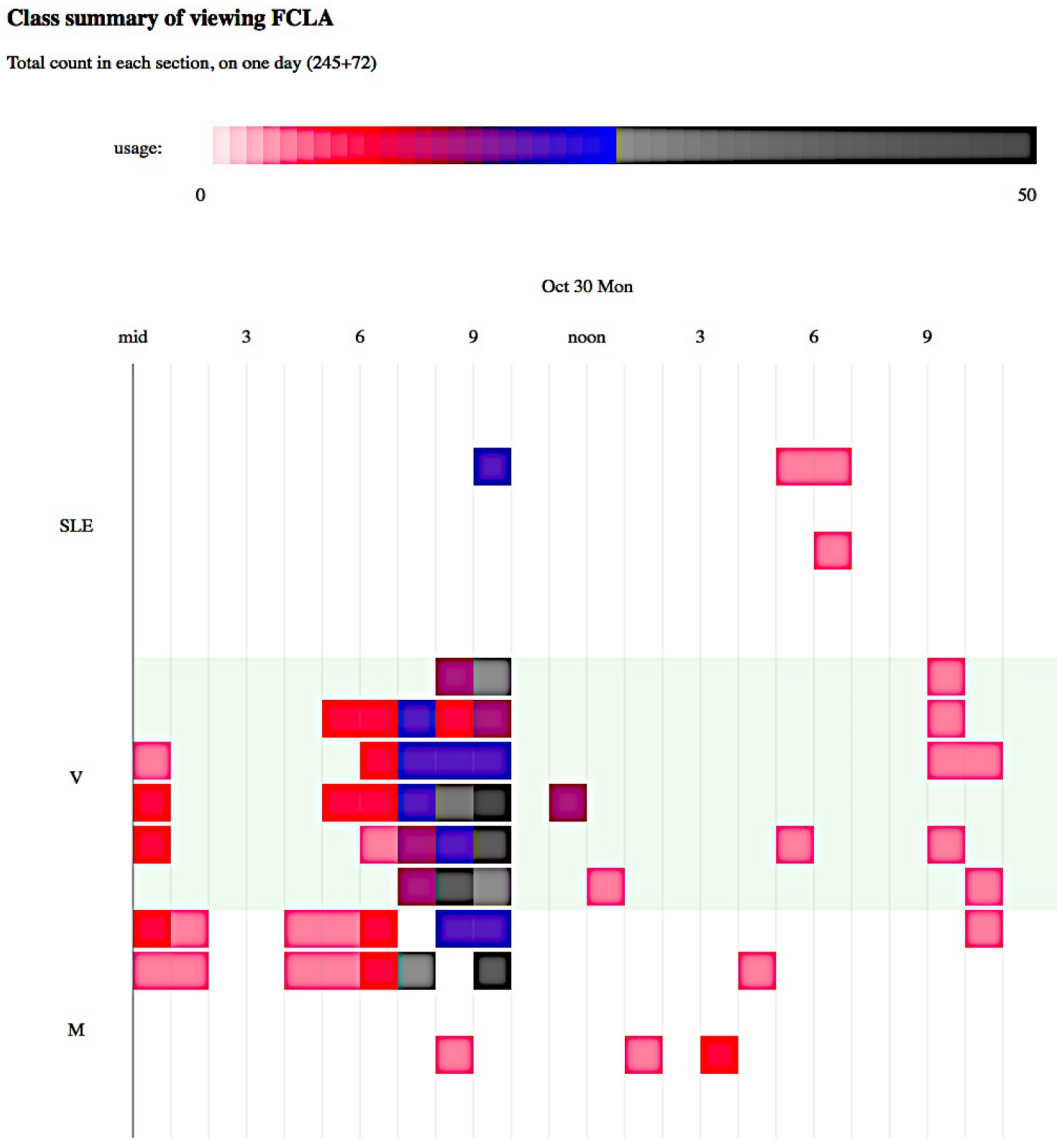
TEXTBOOK USE: HEAT MAP

A user's actions, such as revealing a solution by clicking on a *knowl*, can be recorded along with the time spent on that part of the textbook.



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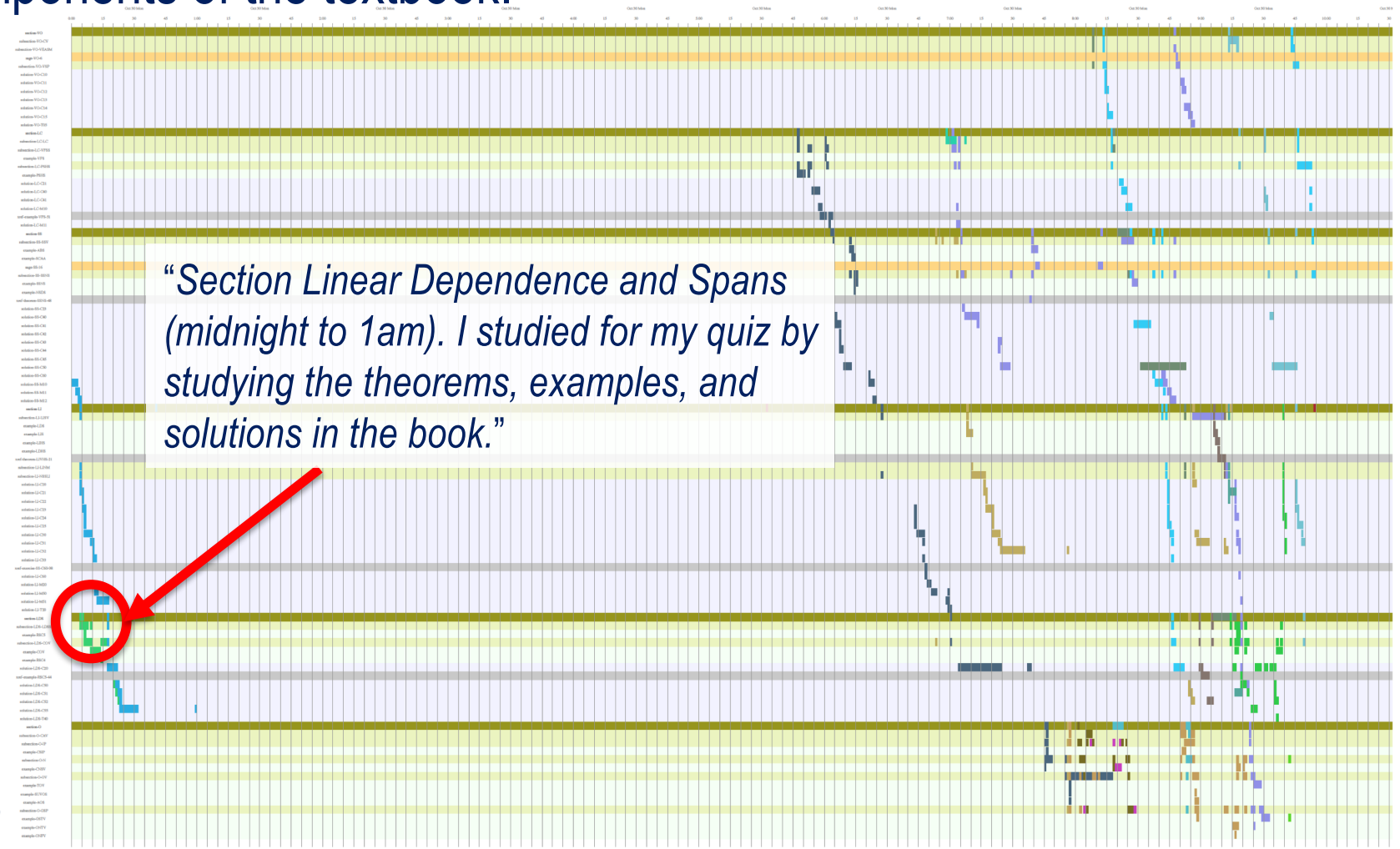
Data organized by individual user, with resolution to the minute and at the level of examples, figures, theorems, exercises, solutions, and other components of the textbook.



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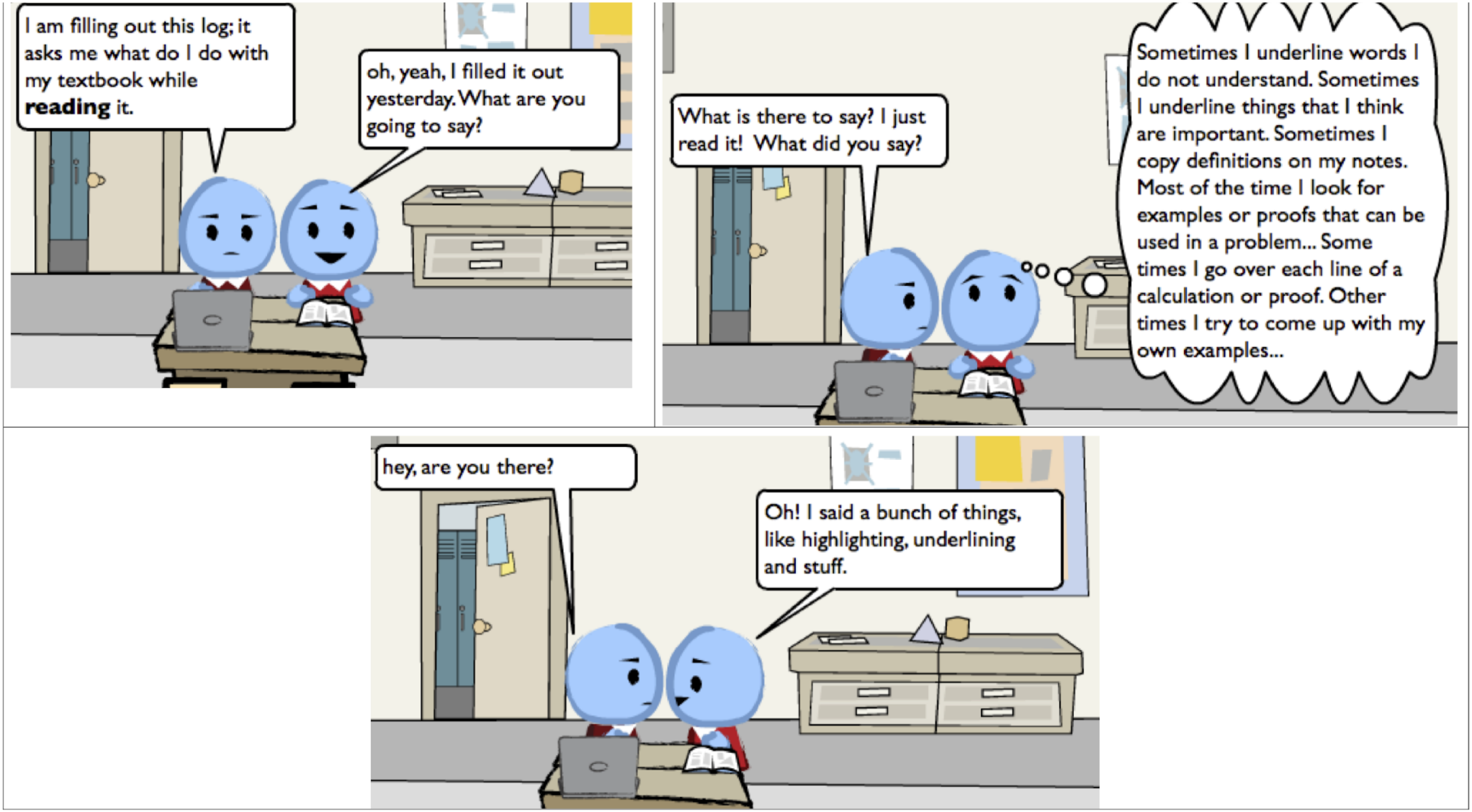
HOW DO YOU READ YOUR TEXTBOOK?



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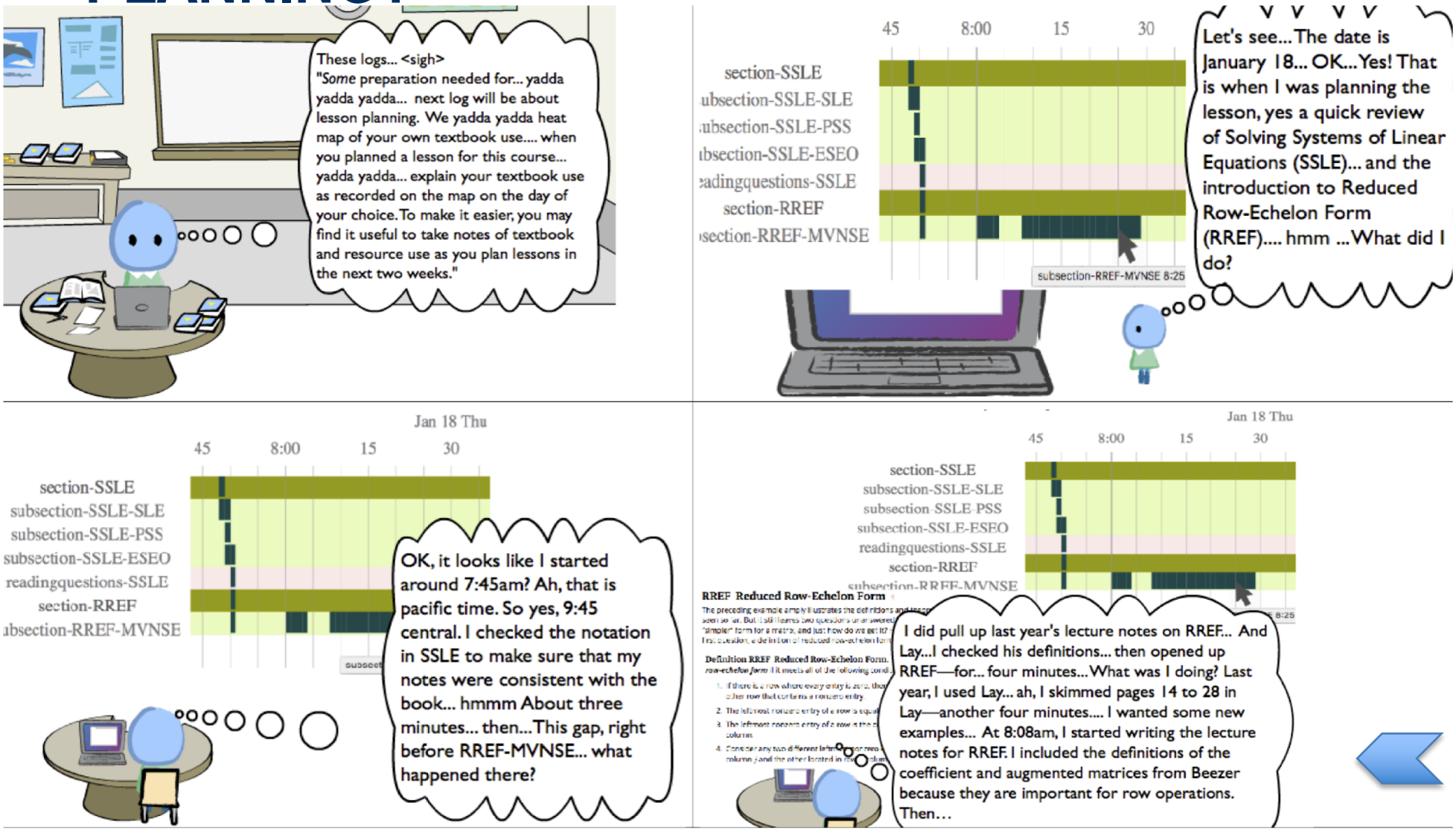
HOW DO YOU USE YOUR TEXTBOOK FOR PLANNING?



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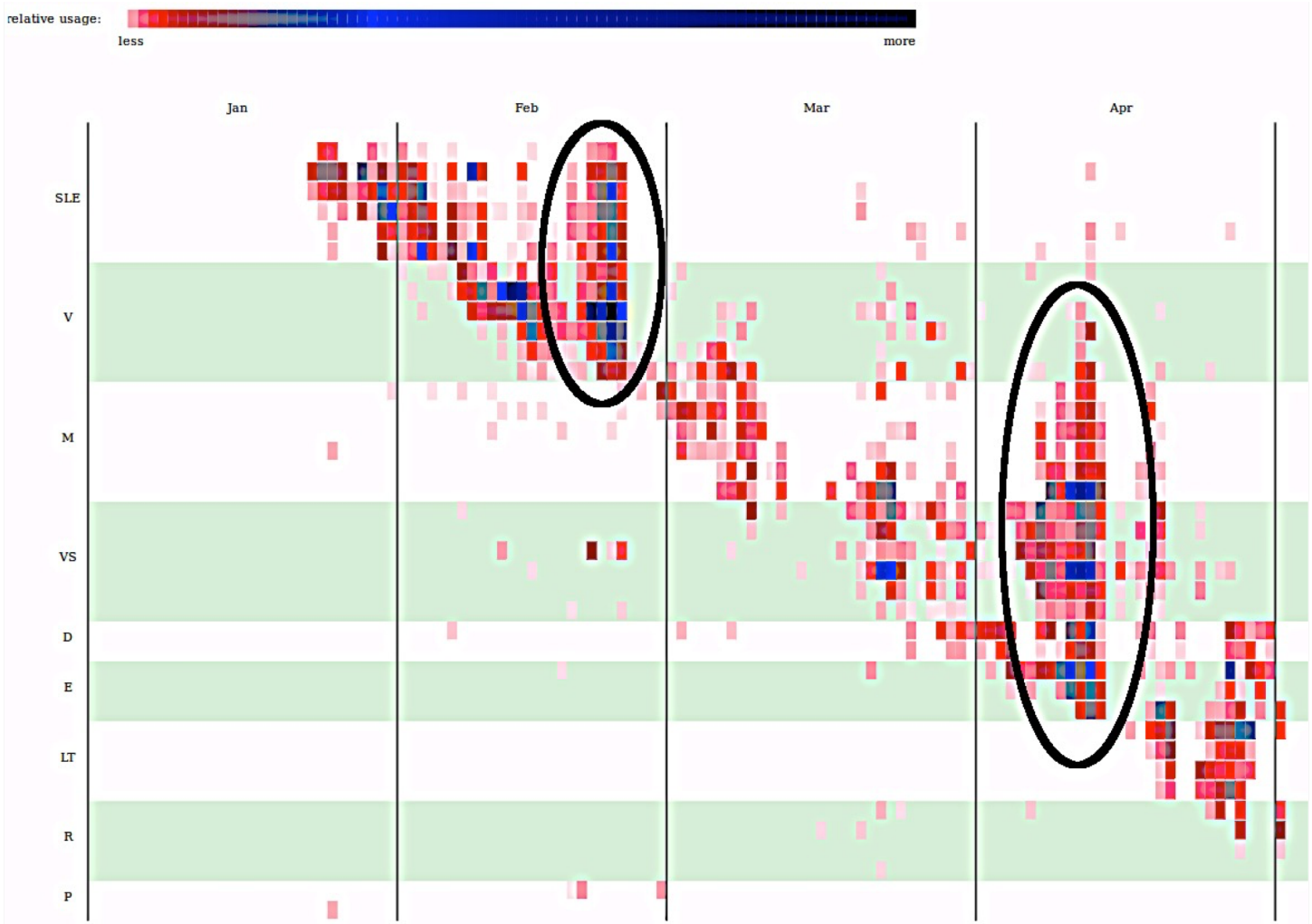
TEXTBOOK USE: EXAMS

ROWS ARE SECTIONS, COLUMNS ARE DAYS



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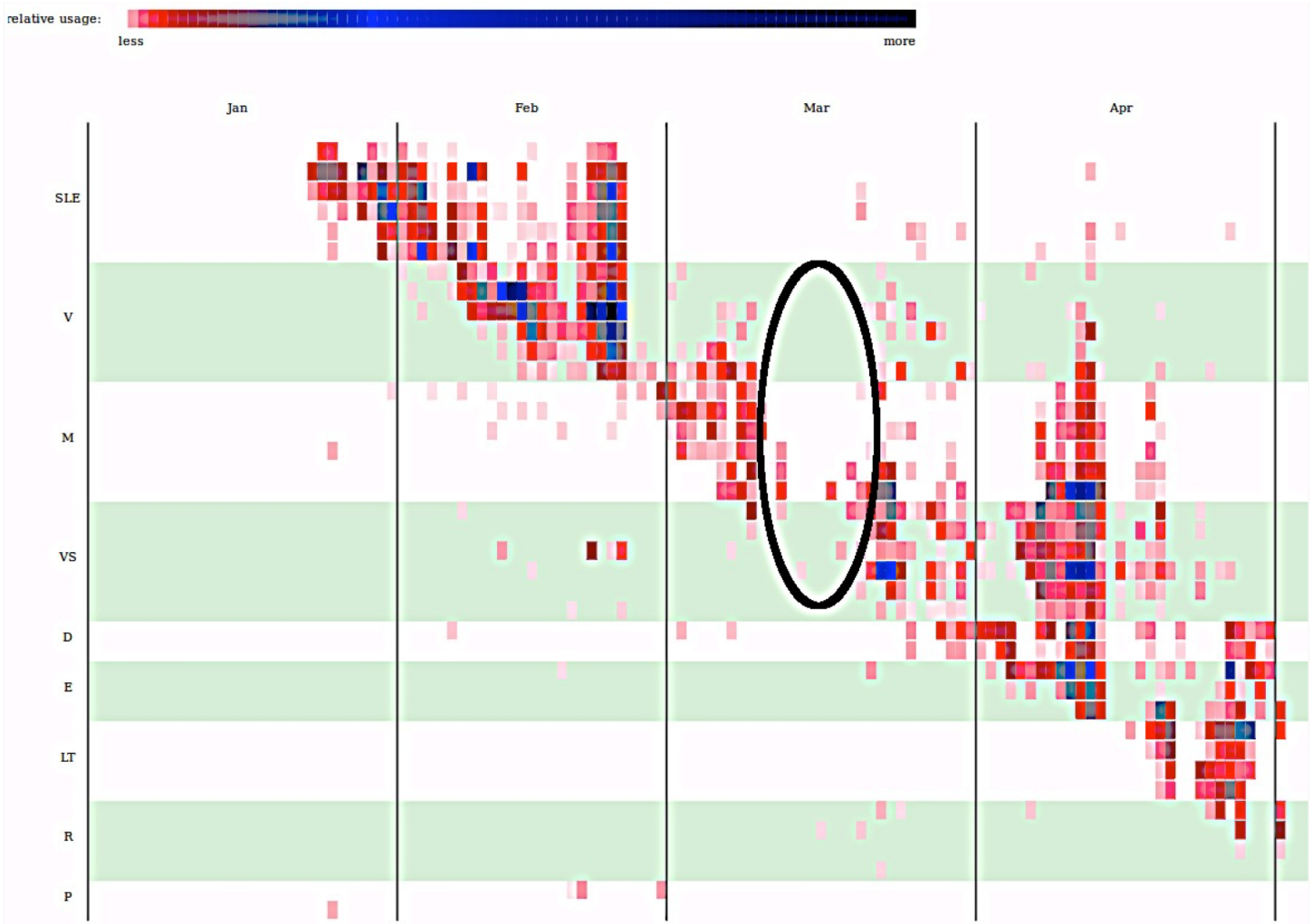
TEXTBOOK USE: SPRING BREAK

ROWS ARE SECTIONS, COLUMNS ARE DAYS



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