UTMOST: Undergraduate Teaching and Learning in Mathematics with Open Software and Textbooks

Joint Mathematics Meetings, Baltimore

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The UTMOST Project

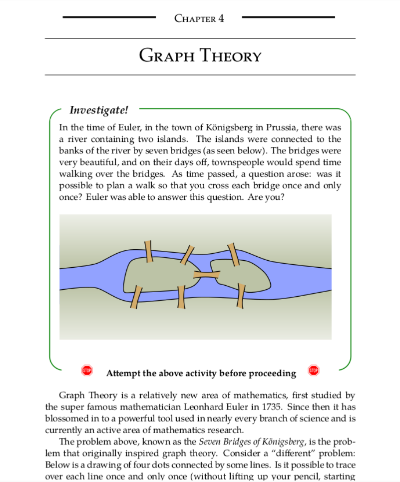
- Development: PreTeXt is an authoring and publishing system for openly licensed textbooks
- Research: studies of student and instructor textbook use concentrating on new online formats

- UTMOST 1: Sage Cell Server, CoCalc, PreTeXt
- UTMOST 2: Pilot research study, PreTeXt development
- UTMOST 3: Large-scale research study, PreTeXt development

PreTeXt *lowers barriers to effective learning*

Barrier: Cost and Portability, Access

- Print versions are very affordable ($\sim$ \$10 – \$20)
- Open licenses $\Rightarrow$ online versions are FREE
- No DRM (Digital Restrictions Management)
- Available: very readable on small screens (phones)
- Every student has the book
- Day Zero: every student has the book! — K. Morrison



Chapter 4

Graph Theory

Investigate!

In the time of Euler, in the town of Königsberg in Prussia, there was a river containing two islands. The islands were connected to the banks of the river by seven bridges (as seen below). The bridges were very beautiful, and on their days off, townspeople would spend time walking over the bridges. As time passed, a question arose: was it possible to plan a walk so that you cross each bridge once and only once? Euler was able to answer this question. Are you?

Attempt the above activity before proceeding

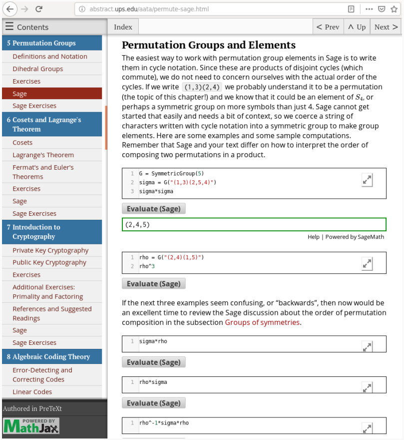
Graph Theory is a relatively new area of mathematics, first studied by the super famous mathematician Leonhard Euler in 1735. Since then it has blossomed in to a powerful tool used in nearly every branch of science and is currently an active area of mathematics research.

The problem above, known as the *Seven Bridges of Königsberg*, is the problem that originally inspired graph theory. Consider a "different" problem: Below is a drawing of four dots connected by some lines. Is it possible to trace over each line once and only once (without lifting up your pencil, starting

Discrete Mathematics: An Open Introduction (Levin)

Barrier: Computing Environments

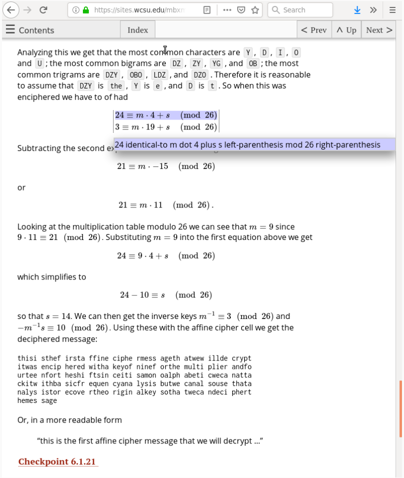
- Mathematica, Maple, Matlab: expensive, licensed
- Sage: open source, powerful, and available
- Sage Cell server
  - Zero setup, no login
  - Up 24 x 7 worldwide
  - Execute inside textbooks
  - Authors create preloaded demonstration code



Abstract Algebra (Judson)

Barrier: Accessibility

- HTML version leverages open standards
- Mathematics via MathJax is screen-reader friendly
- Additional structure included to aid screen-readers
- Automatic for *every* online PreTeXt book
- "Best Practice" advice in PreTeXt *Author's Guide*



Analyzing this we get that the most common characters are `Y`, `D`, `I`, `O` and `U`; the most common bigrams are `DZ`, `ZY`, `YG`, and `OB`; the most common trigrams are `DZY`, `OBO`, `LDZ`, and `DZO`. Therefore it is reasonable to assume that `DZY` is `the`, `Y` is `e`, and `D` is `t`. So when this was enciphered we have to of had

$$24 \equiv m \cdot 4 + s \pmod{26}$$
$$3 \equiv m \cdot 19 + s \pmod{26}$$

24 identical-to m dot 4 plus s left-parenthesis mod 26 right-parenthesis

Subtracting the second e…

$$21 \equiv m \cdot -15 \pmod{26}$$

or

$$21 \equiv m \cdot 11 \pmod{26}.$$

Looking at the multiplication table modulo 26 we can see that $m = 9$ since $9 \cdot 11 \equiv 21 \pmod{26}$. Substituting $m = 9$ into the first equation above we get

$$24 \equiv 9 \cdot 4 + s \pmod{26}$$

which simplifies to

$$24 - 10 \equiv s \pmod{26}$$

so that $s = 14$. We can then get the inverse keys $m^{-1} \equiv 3 \pmod{26}$ and $-m^{-1}s \equiv 10 \pmod{26}$. Using these with the affine cipher cell we get the deciphered message:

```
thisi sthef irsta ffine ciphe rmess ageth atwew illde crypt
itwas encip hered witha keyof ninef orthe multi plier andfo
urtee nfort heshi ftsin ceiti samon oalph abeti cweca natta
ckitw ithba sicfr equen cyana lysis butwe canal souse thata
nalys istor ecove rtheo rigin alkey sotha tweca ndeci phert
hemes sage
```

Or, in a more readable form

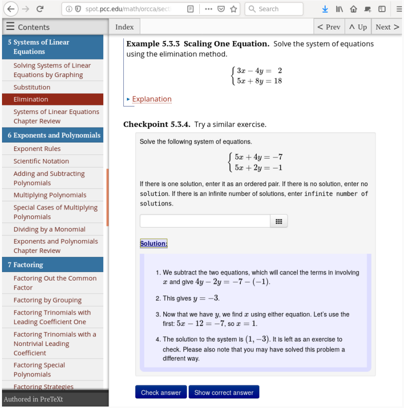
> "this is the first affine cipher message that we will decrypt ..."

Checkpoint 6.1.21

Cryptology Through History and Inquiry (Rocca)

Effective Learning: Embedded WeBWorK Problems

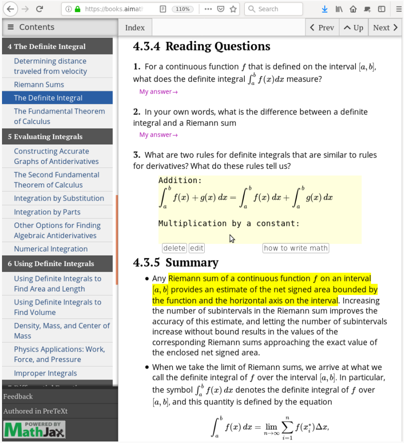
- WeBWorK: system for interactive exercises
- Open source, NSF support
- Author problems in PreTeXt
- Embed problems in output
- Static versions for print
- Extensive practice
- Immediate feedback
- Patient feedback



ORCCA: Open Resources for Community College Algebra (Portland CC Faculty)

Effective Learning: Reading Questions

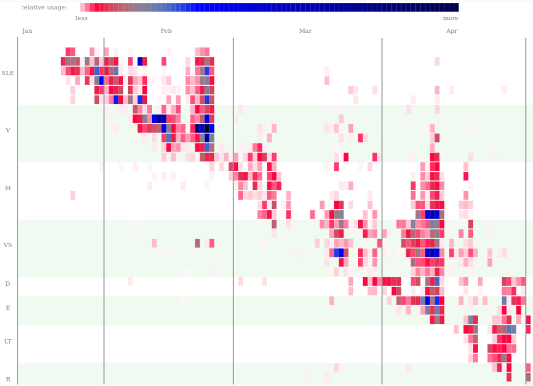
- Promotes active reading
- Promotes daily preparation
- Helps instructor plan use of classroom time
- Students answer questions directly in the book
- Instructor's responses are returned in student's book



Active Calculus (Boelkins)

Effective Learning: Better Research

- PreTeXt enforces explicit structure, mirrored in the HTML version
- With logins and Javascript, analyze reader activity
- Summarize reading and homework activity for instructors?



Heat Map: Across - Days; Down - Sections

A First Course in Linear Algebra (Beezer)

The Research Component

TEXTBOOK USE

SCHOOL OF EDUCATION
UNIVERSITY OF MICHIGAN

RESEARCH QUESTIONS

1. How do instructors and students use these textbooks as they teach and learn?
2. Are there differences in use between dynamic and PDF formats?
3. How can the features in the textbooks be used to alter instruction?

EDUCATION

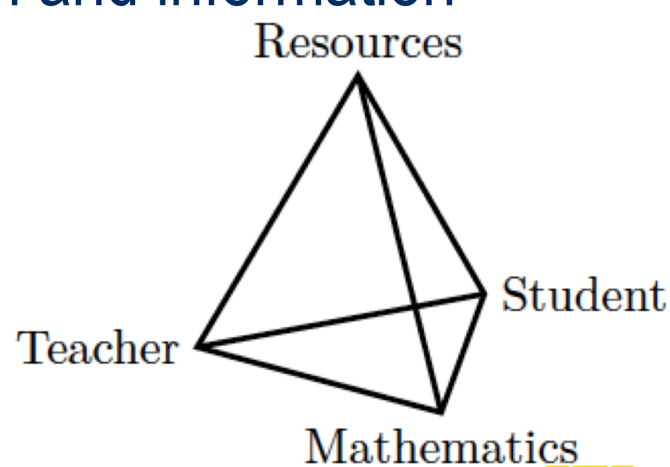
PHASES

- Pilot study (F16-W18): instrument development and testing with 11 instructors, seven case studies, two textbooks
  - Beezer's First Course in Linear Algebra
  - Judson's Abstract Algebra: Theory and Applications
- Current study: Goal 49 sections, 40 instructors, nine case studies, and a third textbook:
  - Boelkin's Active Calculus

EDUCATION

THEORETICAL FRAMEWORK

- Documentational approach
  - An artifact (e.g., a textbook) becomes an instrument once a scheme of use has been defined
  - Resources (a set of artifacts gathered for a particular purpose) become documents once a scheme of use has been defined
  - Schemes of use include rules of action and information about when/why rules are enacted
- Instructional tetrahedron
  - Interactions are mediated by textbook and resources



(Guedet & Trouche, 2009; Pepin et al, 2015; Rezat, 2006)

EDUCATION

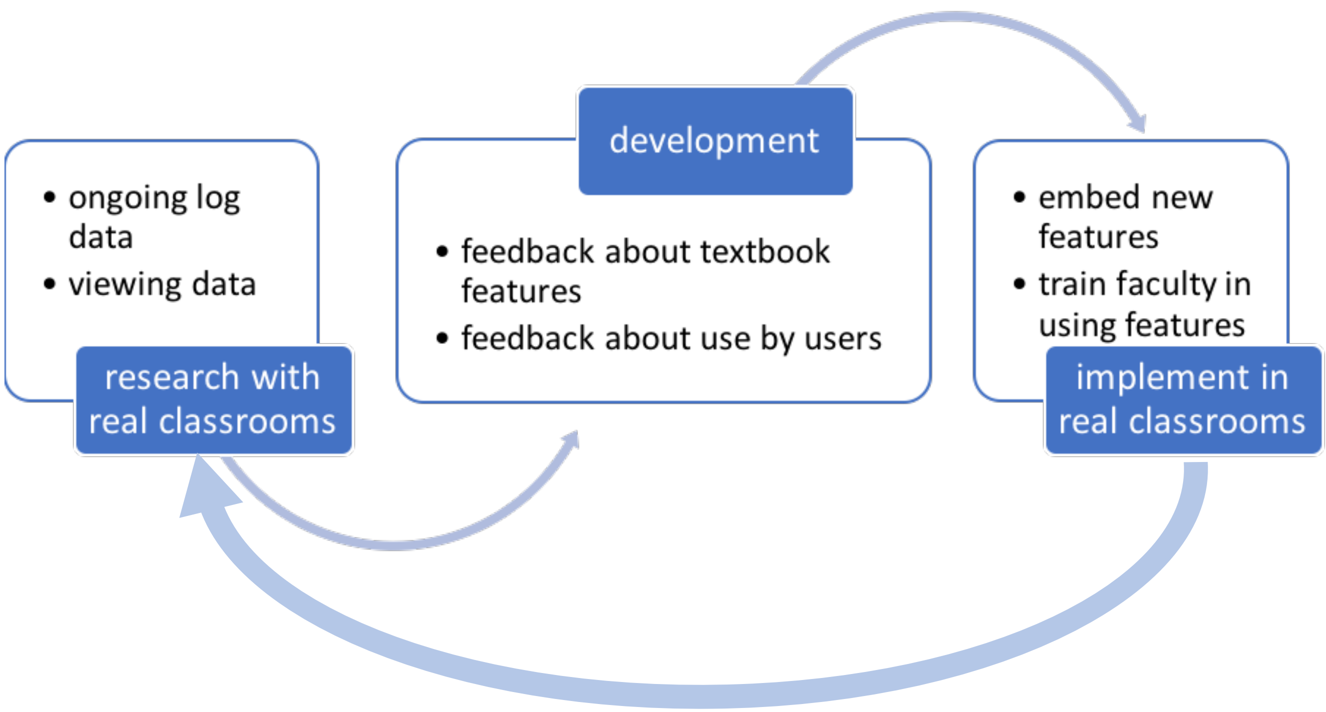
MIXED METHODS EMBEDDED DESIGN

- Qualitative and quantitative data collected simultaneously
  - Ongoing data collection of textbook use via bi-weekly surveys (Logs), viewing data for students and instructor, artifacts
  - Surveys: attitudes and knowledge
  - Student test of knowledge
  - Repeated site visits (interviews, observations, focus groups) before and after Collaborative Workshop
- Recruited so far:
  - 33 instructors in 18 states
  - ~700 students

EDUCATION

VARIOUS CYCLES OF RESEARCH, DEVELOPMENT, AND IMPLEMENTATION

- Data collection: Seven semesters, each with five to nine sections:



EDUCATION

DATA COLLECTION PLAN

	Beginning of Term	2	4	6	8	10	12	14	End of Term
Teacher surveys	X								
Teacher logs		X	X	X	X	X	X		
Site visits for nine instructors:									
Three teacher interviews									
I1: Planning									
I2: Enacting				←—X—→					
I3: Reflecting									
Class observations									
Student focus groups									
Computer-generated data of teacher and student textbook use	∼∼∼	∼∼∼	∼∼∼	∼∼∼	∼∼∼	∼∼∼	∼∼∼	∼∼∼	
Student logs		X	X	X	X	X	X		
Student survey					X				
Student tests	X							X	
Student grades									X

Collaborative workshop with instructors, authors, developers, researchers, in intervening summer for a subset of six instructors

ANALYSIS

- Ongoing analysis within a semester:
  - Student and instructor logs using language processing to inform log design and needs for feature modification
- Analysis across semesters:
  - Resource use, schemes of use, changes due to intervening Collaborative Workshop
  - Reports for individual faculty
  - Aggregate reports for research team
- Aggregate across all data collected:
  - Surveys, tests, and grades → what is the impact for students?
  - Resource use, classroom data → what is the impact on practice?

EDUCATION

UNDERGRADUATE TEACHING AND LEARNING IN MATHEMATICS WITH OPEN SOFTWARE AND TEXTBOOKS

THANK YOU!

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