

# Experience with a Collaborative Annotation/Discussion Tool in the Classroom

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# Discussion Forums: Benefits

- Students can ask questions
  - whenever they have them, not just in class
- And get answers from other students
  - Peer teaching → peer learning
- Teachers can observe trouble spots
- Archival Q&A record
  - knowledge accumulates over time

# Learning Benefits

- Michelle Chi. “Differentiating Four Levels Of Engagement In Learning: The ICAP Hypothesis”
- ICAP Hierarchy of learning modes
  - Interactive (engaging with a peer to explain jointly, attack or support claims, reciprocally teach)
  - Constructive (asking questions, self-explaining)
  - Active (taking notes, annotating)
  - Passive (listening to a classroom lecture, reading)
- Higher modes produce better learning outcomes
  - Measurable effects

# Discussion Forums: Out of Context

- Interrupt reading to visit forum
  - Check Facebook while you're at it....
  - Cost of multitasking/loss of flow
- Hunt for answer to your question
  - When it might not even exist
- Describe/infer question context (“on page 23...”)
  - If question longer than answer, skip
- Find questions you can answer
  - Big effort with no benefit to you

# Idea

Course text provides a **context**

Keep that context during discussion

By placing discussions in the margins

# Nb

- Threaded discussions like a forum
  - But in document margins
- Standard web site
- Faculty sets up class site
  - signs up their class
  - invites students
  - uploads PDFs
- Students discuss
  - Highlight text, enter comments
  - Reply to existing comments

- 174 threads
- me 0
  - ★ 0
  - ? 0
  - Can we justify the 3 angstrom interato...
  - Why is this a consequence of hydrogen...
  - How did we get 3 from 1?**
  - Too many 'is's in this sentence.
  - This paragraph's wording is a little bit c...
  - I feel like I have seen this drawing be...

+ 0 - replies requested

**How did we get 3 from 1?** [Reply Actions](#)  
Anonymous - 18 Mar 2010

**The 1 was the diameter of hydrogen. The 3 is typical interatomic spacing.** [Reply Actions](#)  
Anonymous - 18 Mar 2010

**The 3 and 1 represent 2 different values- 3A is the typical space between all atoms while 1A is the diameter for Hydrogen specifically.** [Reply Actions](#)  
Anonymous - 18 Mar 2010

**So hydrogen atoms are spaced by only 1A when most other atoms are typically spaced between 3A? Am I following you correctly?** [Reply Actions](#)  
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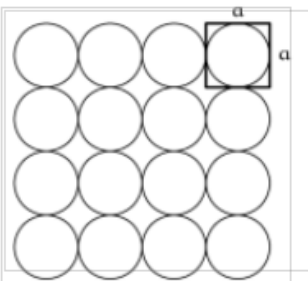
**Why doesn't this vary significantly based on the size of the atom? Or is three just the overall average.** [Reply Actions](#)  
Anonymous - 18 Mar 2010

**As you say, it is based on the size of the atom. Hydrogen is at the very small end, and uranium is at the large end. 3 Angstroms is a good average size to use for the common atoms in ordinary substances. As a \*very\* rough approximation, think of the diameter as 1 Angstrom per shell.** [Reply Actions](#)

5.3.2 Atomic sizes and substance densities

Hydrogen has a diameter of 1 Å. A useful consequence is the rule of thumb is that a typical interatomic spacing is 3 Å. This approximation gives a reasonable approximation for the densities of substances, as this section explains.

Let  $A$  be the atomic mass of the atom; it is (roughly) the number of protons and neutrons in the nucleus. Although  $A$  is called a mass, it is dimensionless. Each atom occupies a cube of side length  $a \sim 3 \text{ \AA}$ , and has mass  $A m_{\text{proton}}$ . The density of the substance is



$$\rho = \frac{\text{mass}}{\text{volume}} \sim \frac{A m_{\text{proton}}}{(3 \text{ \AA})^3}$$

You do not need to remember or look up  $m_{\text{proton}}$  if you multiply this fraction by unity in the form of  $N_A/N_A$ , where  $N_A$  is Avogadro's number:

$$\rho \sim \frac{A m_{\text{proton}} N_A}{(3 \text{ \AA})^3 \times N_A}$$

The numerator is  $A g$ , because that is how  $N_A$  is defined. The denominator is

$$3 \cdot 10^{-23} \text{ cm}^3 \times 6 \cdot 10^{23} = 18.$$

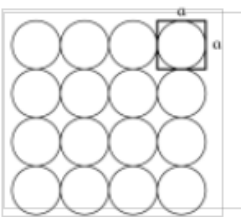
So instead of remembering  $m_{\text{proton}}$ , you need to remember  $N_A$ . However,  $N_A$  is more familiar than  $m_{\text{proton}}$  because  $N_A$  arises in chemistry and physics. Using  $N_A$  also emphasizes the connection between microscopic and macroscopic values. Carrying out the calculations:

$$\rho \sim \frac{A}{18} \text{ g cm}^{-3}$$

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- 3 Why is this a consequence of hydrogen having a dia...
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New note...

The entire class
  Reply Requested
  Anonymous to students

Instructors and TAs
  Myself only



# Benefits

- Discuss as you read, without exiting main view
  - Stay in the flow
- See discussion of what you are reading now
  - Answers that can help you
  - Questions others want answered
- Context is clear
  - No need to explain in question
  - No need to understand from question
- Annotations form “heat map” of trouble spots



# Concrete Mathematics

## 210 BINOMIAL COEFFICIENTS

integer. We usually apply the parallel summation identity when  $r$  and  $n$  are positive integers; but then  $-n-r$  is a negative integer and the hypergeometric (5.76) is undefined. How then can we consider (5.82) to be legitimate? The answer is that we can take the limit of  $F\left(\begin{matrix} 1, -n \\ -n-r+\epsilon \end{matrix} \middle| 1\right)$  as  $\epsilon \rightarrow 0$ .

We will look at such things more closely later in this chapter, but for now let's just be aware that some denominators can be dynamite. It is interesting, however, that the very first sum we've tried to express hypergeometrically has turned out to be degenerate.

Another possibly sore point in our derivation of (5.82) is that we expanded  $\binom{r+n-k}{n-k}$  as  $(r+n-k)!/r!(n-k)!$ . This expansion fails when  $r$  is a negative integer, because  $(-m)!$  has to be  $\infty$  if the law

$$0! = 0 \cdot (-1) \cdot (-2) \cdots (-m+1) \cdot (-m)!$$

is going to hold. Again, we need to approach integer results by considering a limit of  $r+\epsilon$  as  $\epsilon \rightarrow 0$ .

But we defined the factorial representation  $\binom{r}{k} = r!/k!(r-k)!$  only when  $r$  is an integer! If we want to work effectively with hypergeometrics, we need a factorial function that is defined for all complex numbers. Fortunately there is such a function, and it can be defined in many ways. Here's one of the most useful definitions of  $z!$ , actually a definition of  $1/z!$ :

$$\frac{1}{z!} = \lim_{n \rightarrow \infty} \binom{n+z}{n} n^{-z}. \quad (5.83)$$

(See exercise 21. Euler [81] discovered this when he was 22 years old.) The limit can be shown to exist for all complex  $z$ , and it is zero only when  $z$  is a negative integer. Another significant definition is

$$z! = \int_0^{\infty} t^z e^{-t} dt, \quad \text{if } \Re z > -1. \quad (5.84)$$

This integral exists only when the real part of  $z$  exceeds  $-1$ , but we can use the formula

$$z! = z(z-1)! \quad (5.85)$$

to extend (5.84) to all complex  $z$  (except negative integers). Still another definition comes from Stirling's interpolation of  $\ln z!$  in (5.47). All of these approaches lead to the same generalized factorial function.

There's a very similar function called the *Gamma function*, which relates to ordinary factorials somewhat as rising powers relate to falling powers. Standard reference books often use factorials and Gamma functions simultaneously. It's convenient to convert between them if necessary using the

*(We proved the identities originally for integer  $r$ , and used the polynomial argument to show that they hold in general. Now we're proving them first for irrational  $r$ , and using a limiting argument to show that they hold for integers!)*

*How do you write  $z$  to the  $\bar{w}$  power, when  $\bar{w}$  is the complex conjugate of  $w$ ?*

$z^{\bar{w}}$ .

following formula

$$\Gamma(z+1) \\ (-z)! \Gamma(z)$$

We can use powers, when  $z$

$$z^{\bar{w}} = \frac{z^w}{z^{2\Im w}}$$

$$z^{\bar{w}} = \frac{\Gamma(z)}{\Gamma(z-w)}$$

The only provisions formulas give  $\alpha$  Gamma-function

$$\binom{z}{w} = \frac{\Gamma(z+1)}{\Gamma(w+1)\Gamma(z-w)}$$

when  $z$  and  $w$  are

Armed with deducing the identity binomial theorem as we might expect monde's convolution

$$\sum_k \binom{r}{k} \binom{n}{n-k}$$

The  $k$ th term here

$$t_k = \frac{r!}{k!(r-k)!}$$

and we are no longer in the same situation. Whenever we choose the  $k$ , we get  $\alpha$  by (5.85); this coefficient is geometric—as a but as a lower power  $(\alpha-k-1)/(\alpha-k)$  set of parameters hypergeometric

*I see, the lower index arrives at its limit first. That's why  $\binom{z}{w}$  is zero when  $w$  is a negative integer.*

# **ASSESSMENT**

# Usage

- 294 classes with > 100 comments
  - No MOOCs
  - 11218 students
  - 310,010 comments in 199,549 threads
- U. Colorado, Cal State, Dartmouth, Edinborough, Harvard, Middlebury, MIT, NC State, Olin, Pacific, Pitt, Princeton, Puget Sounds, Rochester Institute of Technology, SKKU, Toronto, UC Davis, U. Rhode Island, U. Texas, Vermont, Wesleyan, Yale
- Math, Chemistry, Biology, Stats, Physics, Mech E., CS, Law, Government, Shakespeare, Philosophy
- Frequent re-use

# Nb Usage

Class	School	Comments	Per Student
Approximation Methods	MIT	14258	151
Shakespeare	URI	10641	130
Human-Comp. Interaction	MIT	10420	83
Applied Physics 50	Harvard	5120	97
Applied Math 103	Cal State	4436	61
CopyrightX	Harvard	2688	17
Engineering 2410	Olin	1993	39
Government 2001	Harvard	1324	19
Cell Biology	Rochester	1074	32
CS225	Harvard	880	40
Health Economics	Pacific	807	50
Fysik B	KTH	369	9

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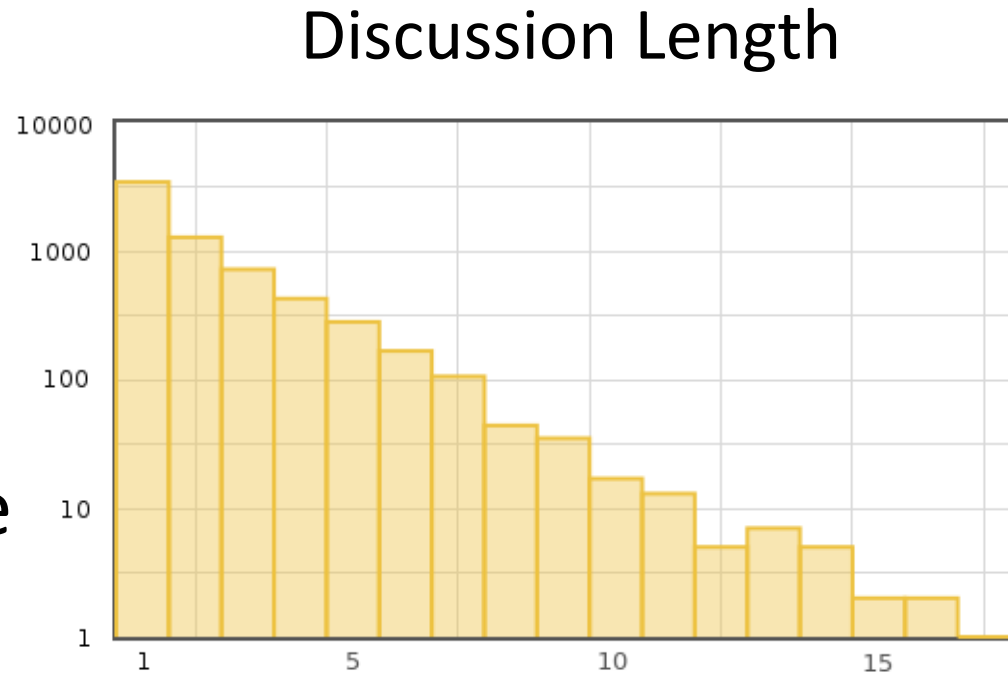
# Best Use Class

- Sanjoy Mahajan, “The Art of Approximation”, MIT
  - Prior to nb, had required paper annotations
- Annotation required
  - But grew to double required amount over term
  - Voluntary usage **after** benefits demonstrated by force
- Extensive in-depth discussions
- 73% questions resolved by other students
  - Most students considered answers “timely”
  - Meaning less than one hour
  - Far faster than staff responses



# Content

- 14,258 Annotations
  - 153/student
  - 310 by faculty
- 77% in discussions
- 13.9 discussions/page
- 3.5 posts/discussion
- 1.4 “long” discussions/page (length > 5)

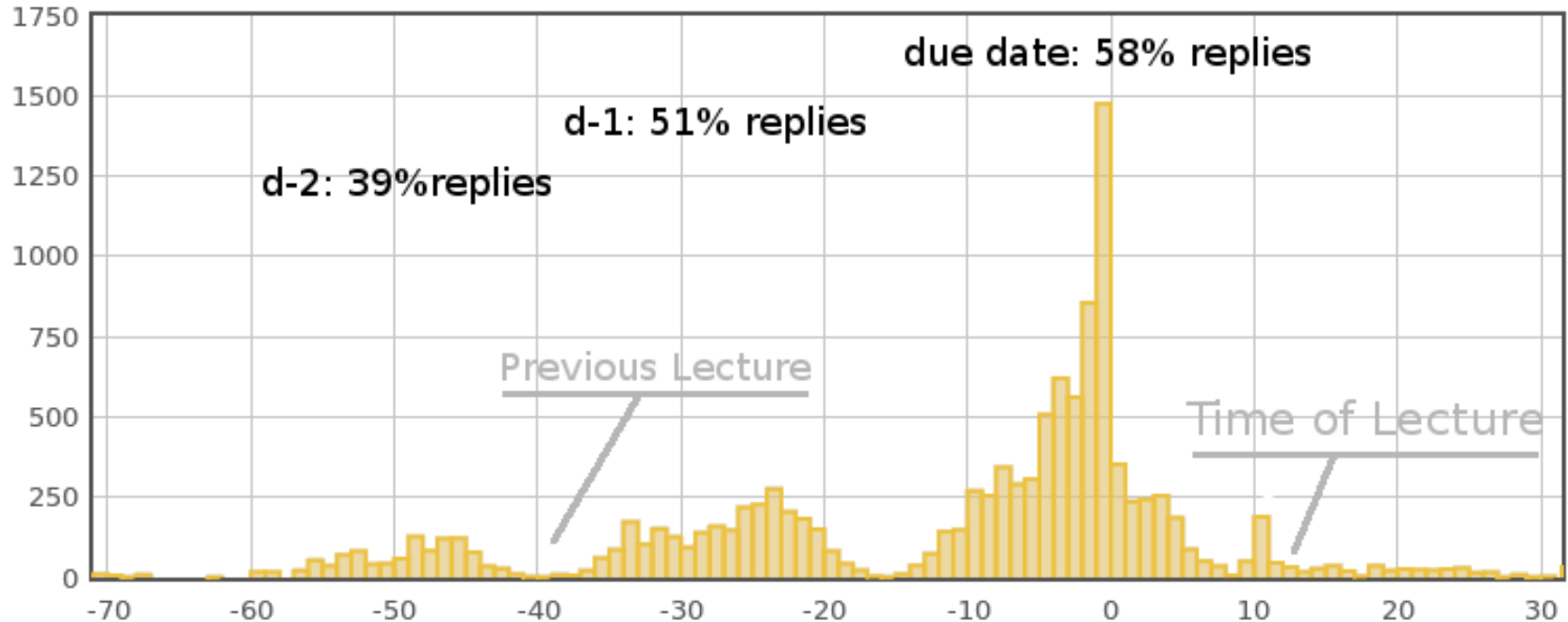


# Content

Percentage	Type
26%	Substantive Commentary (typos, clarification suggestions)
32.1% ...20.3% ...11.5%	Substantive Questions ...about concepts ...about meaning of text
18.5% ...15.7% ... 2.8%	Substantive Answers ...by students ...by faculty
23%	Other (humor, anecdotes, "me too")

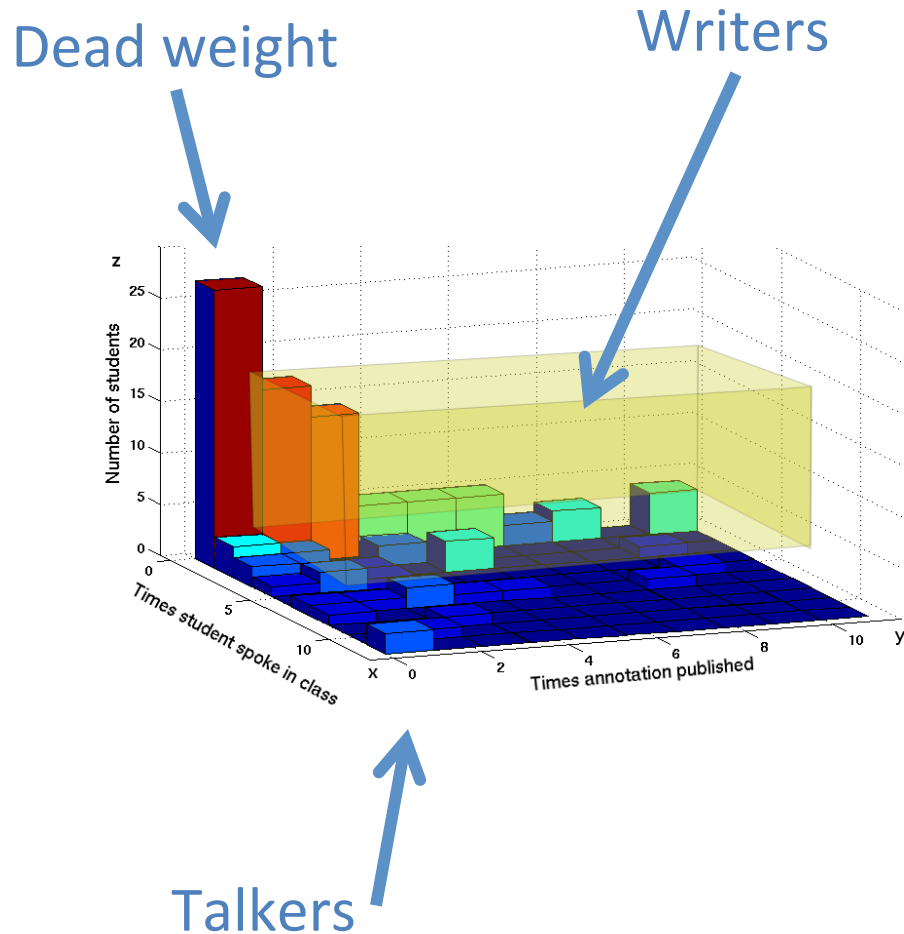
Percentage	Question Resolutions
By students in same thread	50.8%
By students in other thread	12%
By faculty	8.6%
Not resolved	28%

# Timing



- Online reading can be monitored!
- Discussion over multiple days
- Future opportunities to study/improve student study habits

# Participation



- (A different class)
- No correlation between in-class participation and nb commenting
- Nb opens a new channel for shy participants
- Benefits to them and to the class

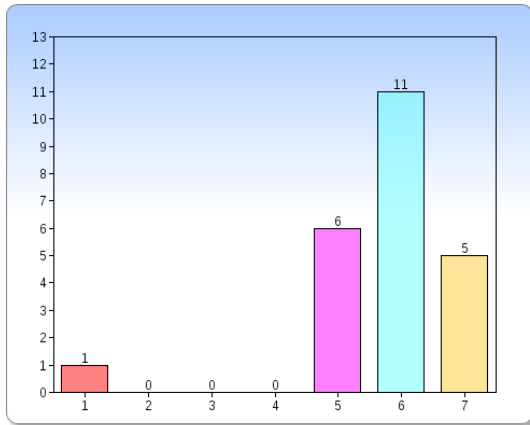
# Student Feedback

- Substantial discussion
  - “Never had this level of in-depth discussion before”
  - “cool to see other people's comments on the material.”
  - “The volume of discussion and feedback was much greater than in any other class.”
- Collective intelligence
  - “I was able to share ideas and have my questions answered by classmates”
  - “I really enjoyed the collaborative learning. The comments that were made really helped my understanding of some of the material.”
  - “Open questions to a whole class are incredibly useful. Everyone has their area of expertise and this is access to everyone's combined intelligence”

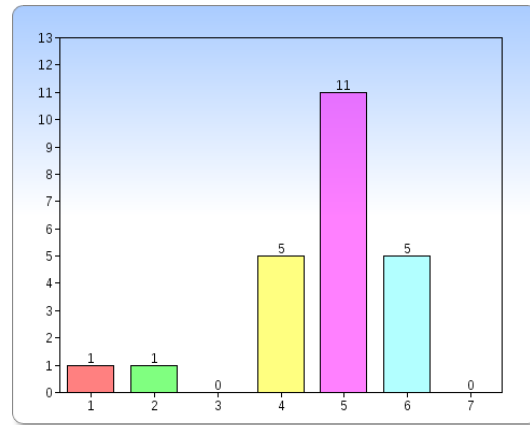
# Student Feedback

- Measuring stick
  - “It's encouraging to see if I'm not the only one confused and nice when people answer my questions. I also like answering other people's questions.”
  - “[NB] helps me see whether the questions I have are reasonable/shared by others, or in some cases, whether I have misunderstood or glossed over an important concept.”

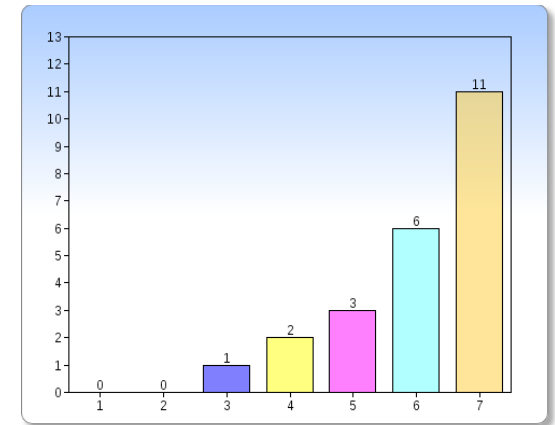
# Faculty Feedback



Satisfaction



Comment  
Quality



Intent to  
reuse

# Improved Online Discussion

- “Students were much more comfortable than they ever are in class with asking one another questions and providing answers. There were **more real debates on NB than I've ever been able to conjure in a classroom.**
- “The **quiet students had really good things to say that they never would have said in class.** The loud students in class that aren't always right, were told when they weren't necessarily correct.
- “Students did establish dialogue among themselves via comments, which delighted me because **even in class this not always happen.**
- “It's a **definite improvement over traditional discussion boards,** which I have tried previously without success.



# Improved In-Class Discussion

- “The **quality of the in-class discussions was much higher** than when I had taught the course previously.
- “Class sessions changed from regular teaching to discuss NB posts. Of course it had become possible **much better to focus on important and difficult points.**
- “They don't just come to class and listen and go home. They know something when they come to class and can participate and ask GOOD questions in class. We were able to have **deeper and more thought provoking discussions** where in the past we couldn't even have a discussion.
- “It was obvious that the vast majority of the class was reading prior to class. This was **very different than prior years.**

# Know your Students

- **“Students came much more alive than in usual class teaching** (even with discussion time). I suddenly noticed their way of thinking, personality, struggles with the material, determinedness to solve big and small problems.
- **“Being able to respond directly to a student meant that even the shy ones got a personalized learning experience**, which never would have happened ordinarily. I think this is extremely beneficial.
- **“I felt more connected to the students** and what they were thinking.
- **“NB has certainly helped me make my classroom more student-centered.**

# Better Teaching

- “It helped uncover misconceptions and **areas of confusion that I did not expect**. I never would have known about many of these things otherwise,
- “The students' comments allowed me to **notice when they were misinterpreting something** from the reading, which I could follow up in class.
- “It really did enable me to **tune a lecture to the students' needs**.
- “I was surprised by how difficult some ideas were for students. For example, one reading had an estimate of the number of bits stored on a CDROM. That whole section was dripping with questions and anxiety in the comments. Thus, I spent the following class helping students get a feel for the physical parameters (e.g. highest frequency of human hearing), which was very helpful, and I **wouldn't have known to do that if weren't for NB**.

# Just a Forum?

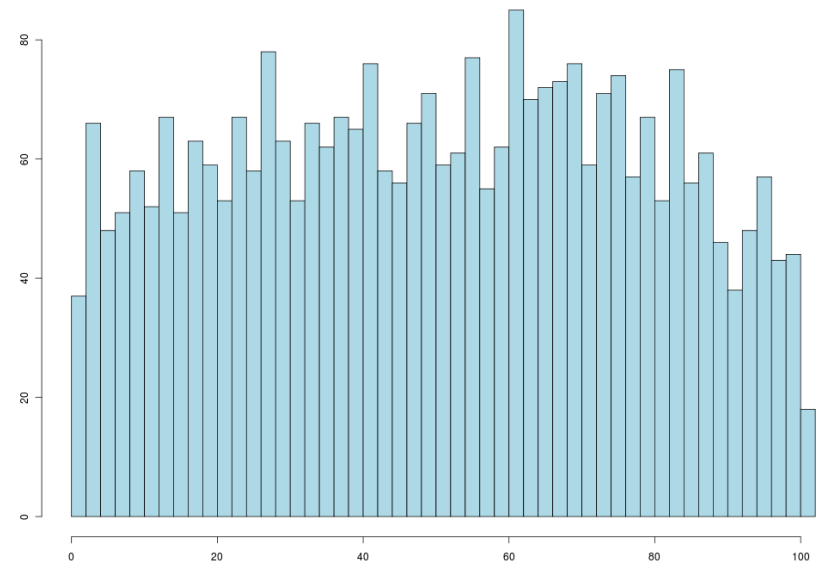
- Most results/quotes could be about any forum
- Though it does indicate that no forum has succeeded this much in students' other classes
- Any evidence annotation approach was better?

# NB-specific Benefits

- Context sensitive comments
  - “How does he get from 1 to 3 here?”
  - “Why?”
  - Easier to ask a question than standard forum
- Responses synthesizing multiple geographically-close threads
  - “The two threads to the left say....”
- 74% of students did not print notes
  - Could have printed, read, checked forum later
  - In-place benefits outweighed those of paper

# Discussion **While** Reading

- Logged all usage
- Identified reading sessions (10 min-1 hour)
- When in interval were replies to comments?
- Evenly distributed throughout reading
- Staying in the flow....
- Hypothesis: this gave critical mass for forum to succeed



# Summary

- NB grounds discussion in the text
  - Provides context for discussion
  - Directs you to relevant discussion while reading
  - Stimulates more substantial participation
- Assessment indicates students
  - Perceive value (after being forced to use it)
  - Leverage context in discussions
  - Engage in substantial peer teaching
- Annotation: personal → collaborative

**LOOKING AHEAD**



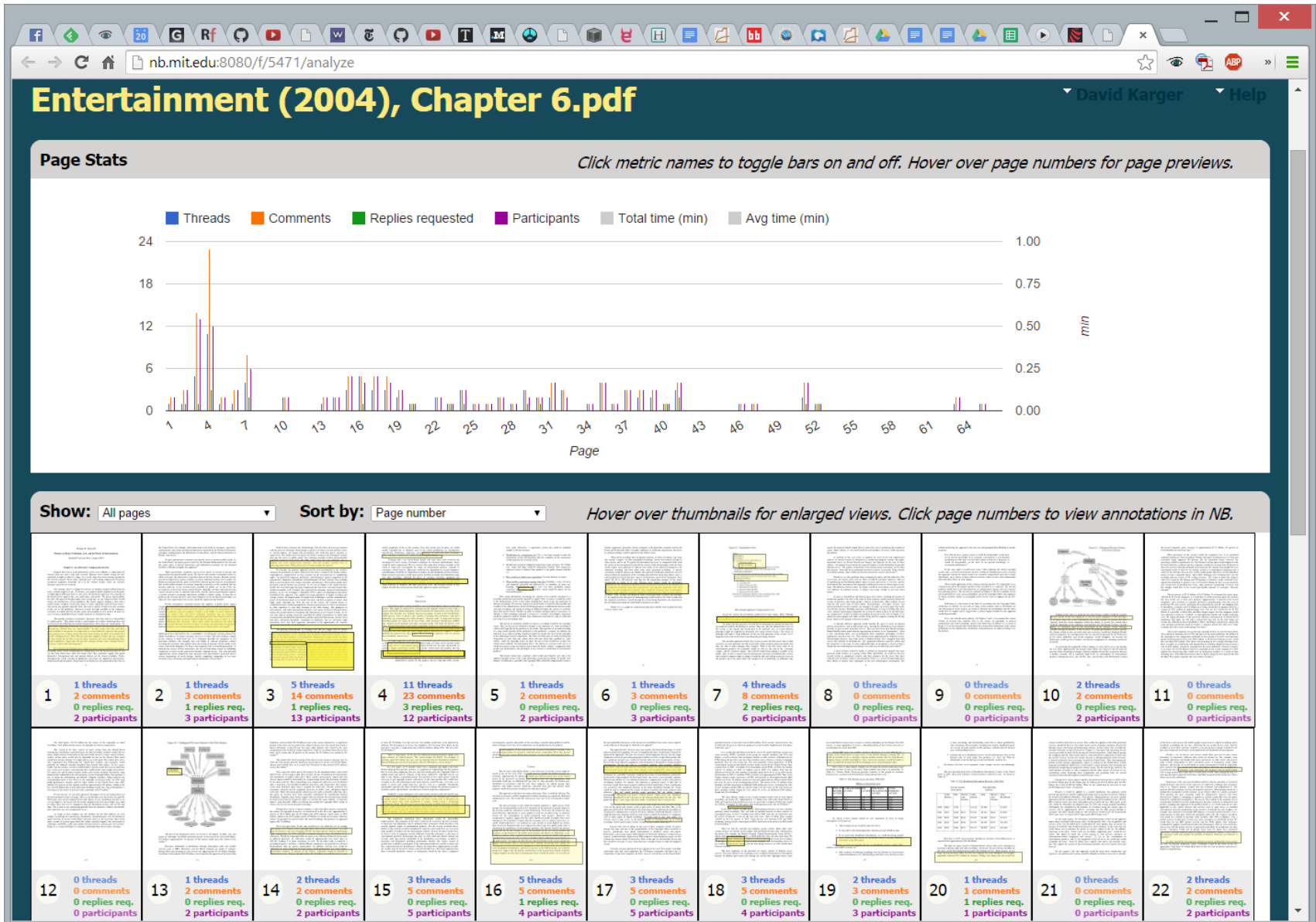
# Annotating Other Media

- Sheet music
- Images
- Video
- Outside the classroom?

# Richer Annotations

- Hand annotations, freeform sketches, diagrams
- Annotations that relate multiple portions of text
  - Linkages between interesting related bits
  - Maps that explain how to navigate the text
- Richer semantics
  - Supporting/contrary evidence
  - Alternative explanations
  - Questions and answers
- Annotate the annotations?
  - Circles back to hypertext...

# Analytics



# Annotations are Content

- Mass of student-contributed material
- How to use it?
  - Preserve to benefit future students?
  - Incorporate into text?
  - Curate, keeping only the good stuff?
- Surely all this content can provide value to future students?

# Journey vs. Destination

- To date, all repeat courses **discard** all previous annotations
- ICAP: the (interactive) process of dialog through annotation is more valuable for learning than the product of (previous students') discussions
- Even if you could create the perfect textbook, so nobody had to ask questions, you shouldn't!
- Opportunity: keep annotations that stimulated substantive discussion

# Curation Interface

The image displays a web-based curation interface with two overlapping windows. The background window shows a page titled "Contents of Homework" with a table of assignments and a "Duplicate File" dialog box. The foreground window shows a similar page with a "Duplicate File" dialog box that is open, displaying a list of threads to be duplicated.

**Background Window: Contents of Homework**

Sort by  $\downarrow$  date added  $\downarrow$  name

Name	Assignment	Download PDF	St
<b>Duplicate file</b>			
<b>Duplicate File</b>			
Filter Threads...			
Show me <input type="text" value="10"/> threads $\downarrow$			
<input type="text" value="that have the most student participation"/> <input type="text" value="randomly"/> <input type="text" value="that have the most responses"/> <input type="text" value="that have the most student participation"/> <input type="text" value="that have the longest initial post"/>			
<input type="checkbox"/> PS4 Solutions	No		
<input type="checkbox"/> PS5	No		
<input type="checkbox"/> ps5-solutions	No		
<input type="checkbox"/> PS6	No		
<input type="checkbox"/> PS6-Solutions	No		

**Foreground Window: Duplicate File**

**Duplicate File**

- 2 Does this mean that we have two different (independent) ...
- 2 what happens if both buckets have the same number of el...
- 3 does every team play the same number of games in total?...
- 6 Does this mean we need to come up with an algorithm to ...
- 4 Are we assuming there is a feasible flow here in problem 4...
- 3 Why are TxS and SxT swapped?
- 4 What is the formal definition of a perfect bash function? D...
- 2 What does "description" exactly mean? Space used?
- 2 This just means some flow with value  $v$ , not that the maxi...
- 5 Do s, t, u, belong to the same graph (i.e. s and u may be ...

Buttons: ,

<input type="checkbox"/> ps5-solutions	No			
<input type="checkbox"/> PS6	No		me 6 unread 1	all 17
<input type="checkbox"/> PS6-Solutions	No			

# Annotations → Content Editing

- Students enrich the content through annotation
- Could permit them to enrich it by editing
- At one extreme, Wikipedia
  - Egalitarian management of content
- At other, sole author
- Is there a middle ground?
  - Students propose enhancements, faculty accept
  - Student create “alternate narratives” that coexist with faculty version