

Divide and Correct: Using Clusters to Grade Short Answers at Scale

Michael Brooks^{1,2}, Sumit Basu¹, Chuck Jacobs¹, Lucy Vanderwende¹

Learning At Scale 2014: Assessment

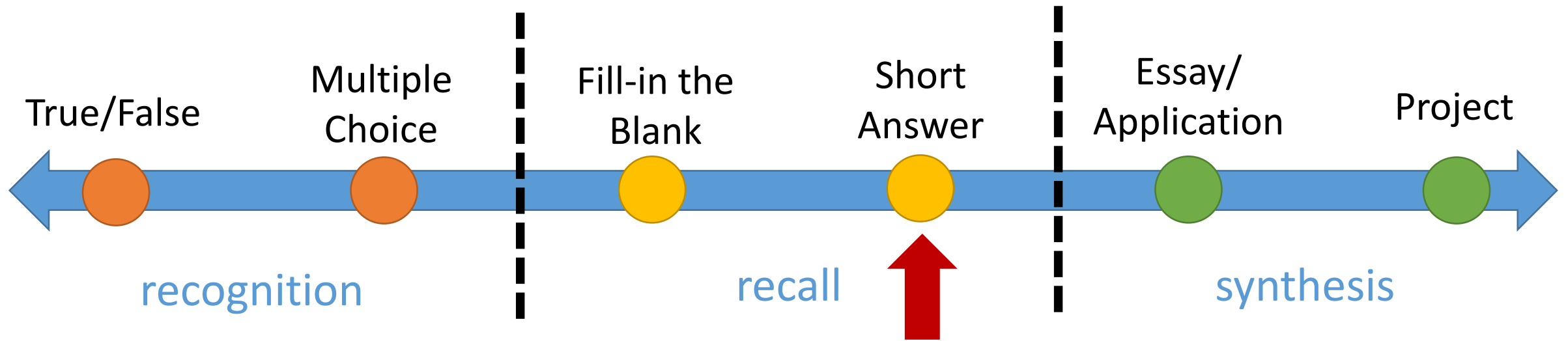
March 5th, 2014, Atlanta

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Not All Tests Are Created Equal



Laufer and Goldstein, 2004, on the difficulty of Recall tasks vs. Recognition

Anderson and Biddle, 1975, "On Asking People Questions About What They are Reading."

Grading Is More than Assigning Scores

- Grading practices
 - Grading is **complex and individualized**
 - Maintaining consistency between students is a challenge
- Impact beyond grades
 - Opportunity for rich feedback to students
 - Getting a snapshot of student understanding
 - Adapting teaching to student needs

What Can We Do with Short Answers at Scale?

- Automatic Grading

- Hand-constructed answer templates, regular expressions
- Paraphrase recognition (C-Rater)
- Similarity metric between response and answer key

Mitchell et al. 2002; Nielsen et al. 2009; Coursera

Leacock & Chodorow 2003

Mohler & Mihalcea 2009; Mohler et al. 2011; Hahn & Meurers 2012

- Peer Grading

- Debiasing and aggregation
- Crowdsourced grading
- Possible learning benefits

Piech et al. 2013; Reily, Finnerty & Terveen 2009

Weld, Adar & Chilton 2012

Sadler & Good 2006

Our Approach: Divide and Correct

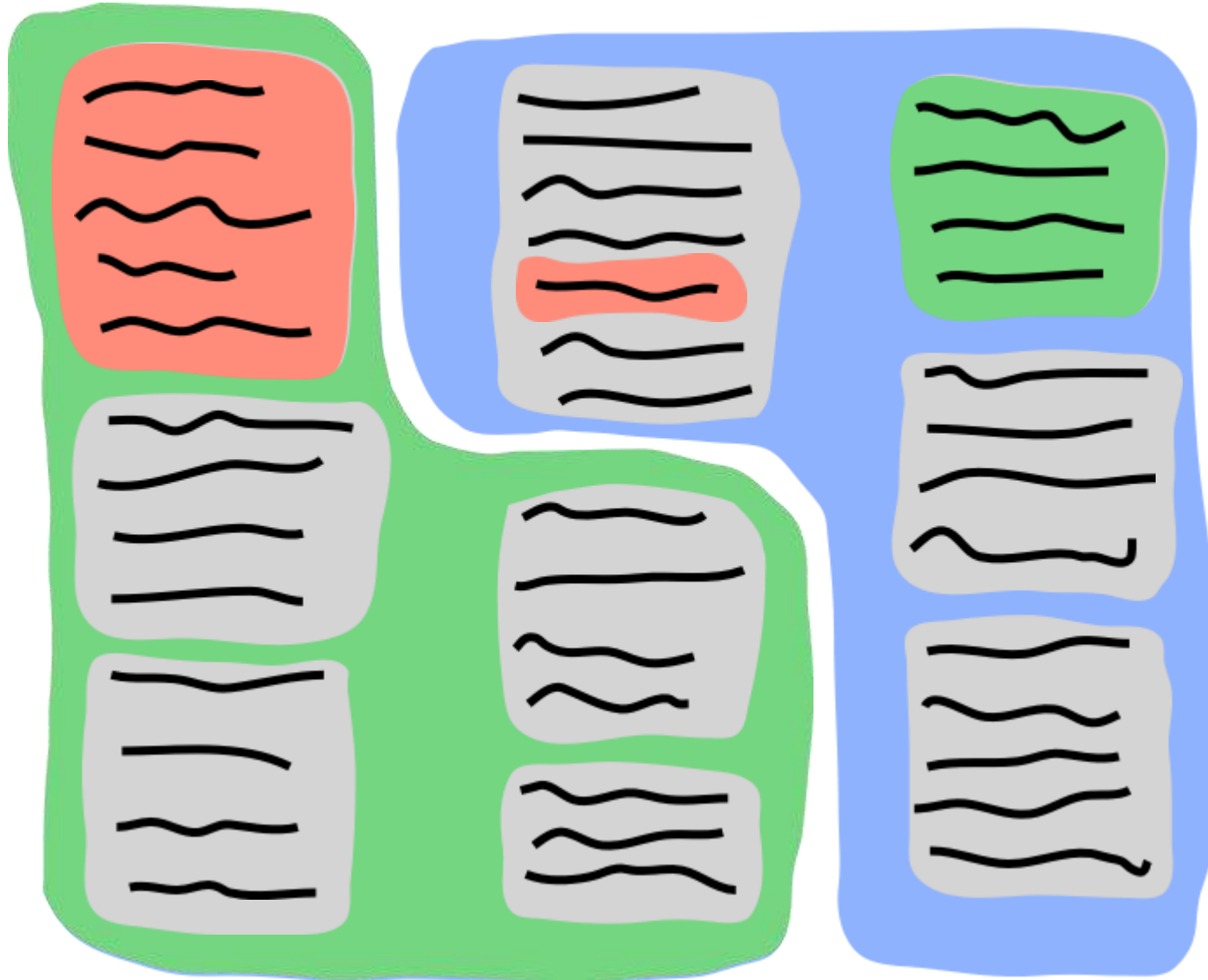
Automatically group student answers into a **hierarchy of clusters***

Teachers give **grades, feedback** on clusters, subclusters, and answers

Amplify teachers' capabilities

*Basu, Jacobs, & Vanderwende. 2013. Powergrading: a Clustering Approach to Amplify Human Effort for Short Answer Grading.

Grading Clustered Short Answers



**What about
real teachers?**

Do clusters make sense?

Can they find outliers?

Is it confusing?

Design

Clustered Grading Interface

Power Grader Question 6: Who or what makes federal (national) laws in the US? Instructions ? Done Grading

14:54 Grading Feedback

Clusters

- x53 [miscellaneous]
supreme legislature executive federal
us court people laws
- x27 **president, congress**
legislative combination along branch
passes corporations signs president
presidential order can supreme veto
signed sign court special effect
interest groups law laws bill sent pass
president's people favors senate
members congress
- x16 **judicial branch**
judicial branch government

Subclusters

- x31 [miscellaneous]
supreme federal court us laws
the house and senate make laws, not th...
- x11 [miscellaneous]
executive people
- x9 [miscellaneous]
legislature
- x1 [miscellaneous]

Answers

x22	supreme court	the house...
x2	the supreme court	the house...
x1	supreme court.	the house...
x1	the us supreme court	the house...
x1	the supreme court makes laws in the us.	the house...
x1	suprem court	the house...
x1	suprime court	the house...
x1	federal court	the house...
x1	supreme court? they at least verify if federal laws are constitutional	the house...

1 subcluster selected

Mark Unread Flag

Grading

Incorrect Partial Correct

Feedback Clear Save

the house and senate make laws, not the courts

Answer Key

Q: Who or what makes federal (national) laws in the US?

Congress

Senate and House

Senate and House of Representatives

Clustered Grading Interface Design

- Exploratory navigation
- Grade and feedback is inherited and overridden

The screenshot shows the Power Grader interface for a question titled "Question 6: Who or what makes federal (national) laws in the US?". The interface is divided into several panels:

- Clusters:** A list of clusters with their counts and associated terms. The cluster "x81 senate and house of representatives" is highlighted in blue. Other clusters include "x103 legislative branch", "x40 congress (senate and house of representatives)", "x16 senate", "x13 house and senate", and "x53 [miscellaneous]".
- Subclusters:** A list of subclusters with their counts and associated terms. The subcluster "x16 senate" is highlighted in blue. Other subclusters include "x40 congress (senate and house of representatives)" and "x13 house and senate".
- Answers:** A list of answers with their counts and associated terms. The answer "x9 senate" is highlighted in yellow. Other answers include "x1 senate?", "x5 the senate", and "x1 the senate?".
- Grading:** A section with buttons for "Mark Unread", "Flag", "Incorrect", "Partial", and "Correct".
- Feedback:** A section with buttons for "Clear" and "Save", and a text input field containing "the house also makes laws".
- Answer Key:** A section titled "Q: Who or what makes federal (national) laws in the US?" with a list of possible answers: "Congress", "Senate and House", and "Senate and House of Representatives".

Clustered Grading Interface Design

- Exploratory navigation
- Grade and feedback is inherited and overridden
- Visual summary of cluster contents

answers

answer at center of cluster

x81 senate and house of representatives

combination congress legislative vote
branch composed us house
government senate united legislature
representatives representatives veto
senators president u s laws proposed

words contained in answers

19:47

Grading

Feedback

Clusters

Subclusters

Answers

x378 congress

congress us makes house senate federal laws

x103 legislative branch

legislative legislative executive writes branch legislation
legislators senate congress judicial laws branches

x81 senate and house of representatives

combination congress legislative vote branch composed us
house government senate united legislature representatives
representatives veto senators president u s laws proposed

x53 [miscellaneous]

supreme legislature executive federal us court people laws

x27 president, congress

legislative combination along branch passes corporations
signs president presidential order can supreme veto signed
sign court special effect interest groups law laws bill sent
pass president's people favors senate members congress

x16 judicial branch

judicial branch government

x15 government

federal branches government

← Select a cluster to start

see <http://bit.ly/powergrading>

Nothing selected

Mark Read

Flag

Grading

Incorrect

Partial

Correct

Feedback

Clear

Save

Answer Key

**Q: Who or what makes federal
(national) laws in the US?**

Congress

Senate and House

Senate and House of Representatives

Evaluation

Flat Grading Interface (Baseline)

The screenshot displays the Power Grader interface for a question: "Question 4: What is the economic system in the United States?". The interface includes a top navigation bar with "Power Grader", "Question 4: What is the economic system in the United States?", "Instructions", and a "Done Grading" button. Below the navigation bar, there is a timer showing "15:55" and tabs for "Grading" and "Feedback".

The main area shows a list of student answers, each with a count (e.g., x1, x2, x5) and a color-coded bar indicating the grade. The selected answer is highlighted in light blue. The answers are:

- x1 'mixed' economy (need capitalist or market)
- x1 a bad one (capitalist or market)
- x1 a capitalist economy
- x1 a capitalist economy with some socialist aspects like medicare, social security, and government oversight organizations like the fda and the health department
- x1 a combination of capitalism + command
- x1 a corporate welfare guised as a capitalist system. (Selected)
- x1 a free enterprise and capitalism.
- x2 a free market system
- x1 a market economy
- x5 a market system
- x1 a market system of stocks and bonds
- x1 a market system that runs the economy.
- x1 a regulated free-market capitalist system
- x1 a set of laws we have to follow
- x1 a system of economics (be more specific)
- x1 a total failure.

The right sidebar contains the following sections:

- 1 answer selected**: Includes "Mark Unread" and "Flag" buttons.
- Grading**: Includes "Incorrect", "Partial", and "Correct" buttons.
- Feedback**: Includes "Clear" and "Save" buttons and a text input field.
- Copy previous feedback:** A list of feedback comments: "be more specific", "capitalist or market", and "need capitalist or market".
- Answer Key**: Shows the question "Q: What is the economic system in the United States?" and the correct answers: "capitalist economy" and "market economy".

Questions

Preferences: Did teachers like it?

Efficiency: Was grading speed improved?

Quality: Was accuracy affected?

Feedback: Was giving feedback supported?

Reflection: Were teachers able to reflect on student answers?

Study Design

- Online study
- Within-subjects, 20 minute tasks, 1 hour total
- Tutorial video for each interface
- Gathered log data and questionnaire answers
- Examined speed, accuracy, feedback, and comments

Participants

- Recruited 25 teachers
- Screened for **teaching experience**
- Teaching experience was vetted individually

Subject Area	Participants
Government, Politics, Civics	9
English	23
Literature	12
STEM areas	12

Grade Level	Participants
Middle/high school	22
College/graduate	12

Answer Data for Evaluation

- Powergrading Short Answer Grading Corpus
 - Selected 2 questions from the US Citizenship Exam
 - Total of 698 answers per question, from Mechanical Turk

bit.ly/powergrading

	Question	Distinct answers	Avg. words/ans.
Q4	What is the economic system in the United States?	196	3.9
Q6	Who or what makes federal (national) laws in the US?	205	6.4

Results

Preferences

*“When initially viewing the video on this interface, I was a little worried that it might be somewhat complicated and time consuming due to the subcategories. However, I was incorrect. This interface was **quite efficient and easy to use.**” (P15)*

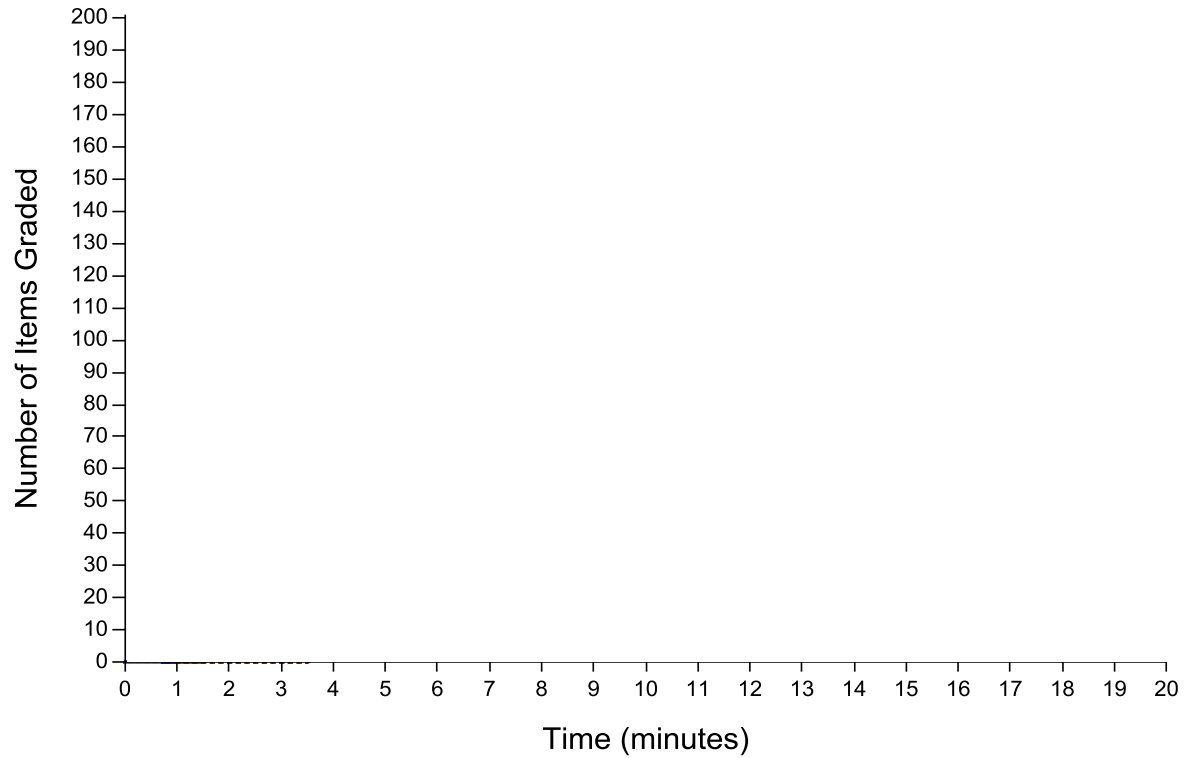
*“[The clustered interface] **worked very well** for me, especially given the large number of total responses. I found [the flat interface] quite tedious ... The clustered interface] **helped me to identify student patterns** in thinking quite well.” (P12)*

	Clustered	Flat (Baseline)
Faster	21	4
More Enjoyable	20	5
Easier to Use	20	5
More Effective	19	6
Better Overall	21	4

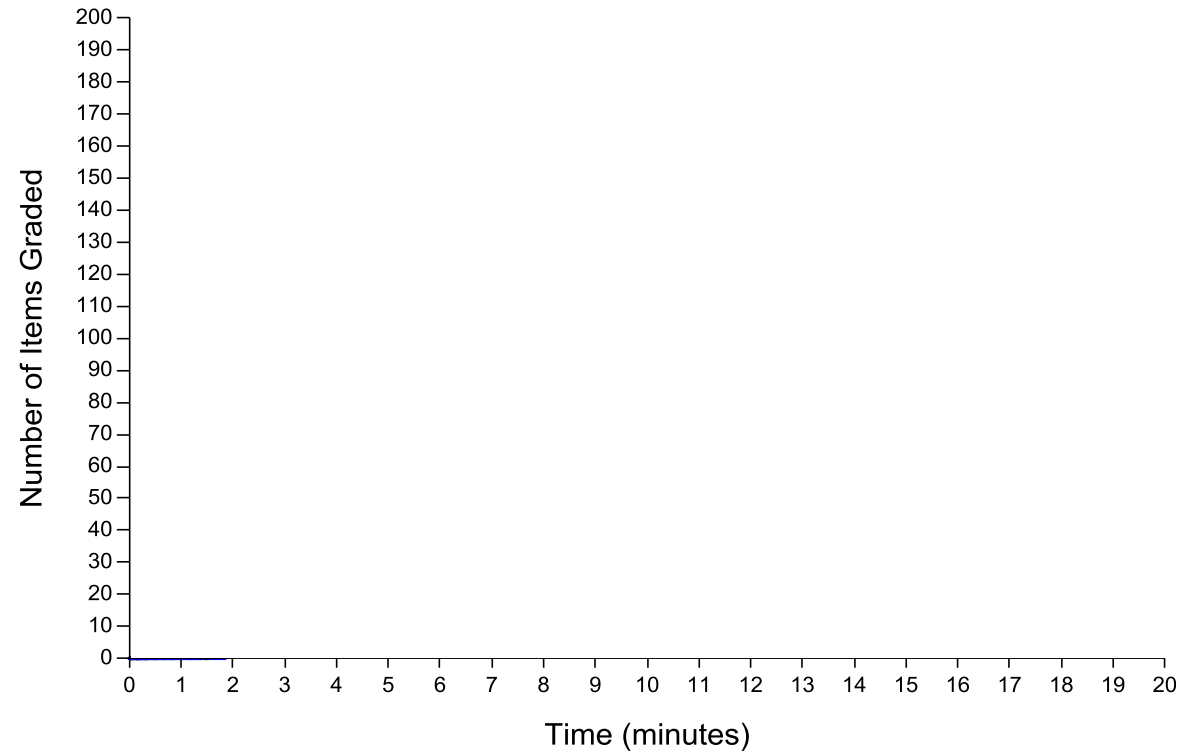
21 participants preferred the Clustered interface



Efficiency

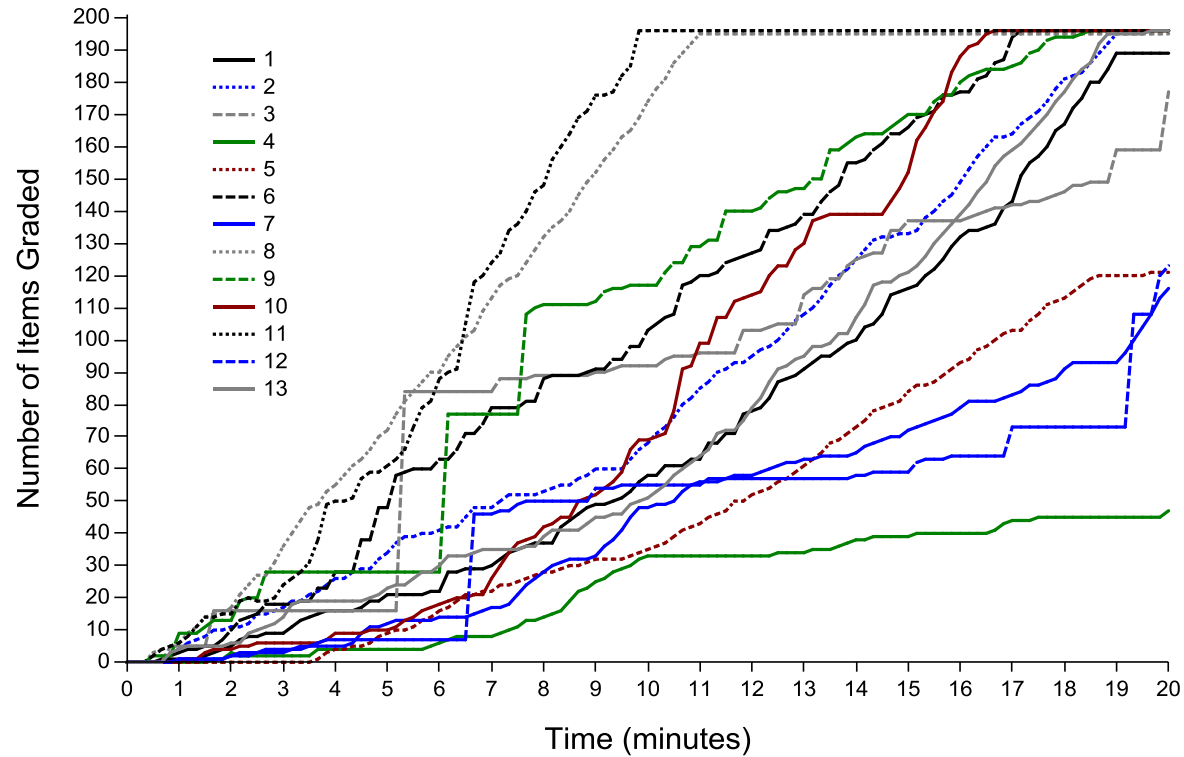


Flat Interface, answers graded vs. time for Q4

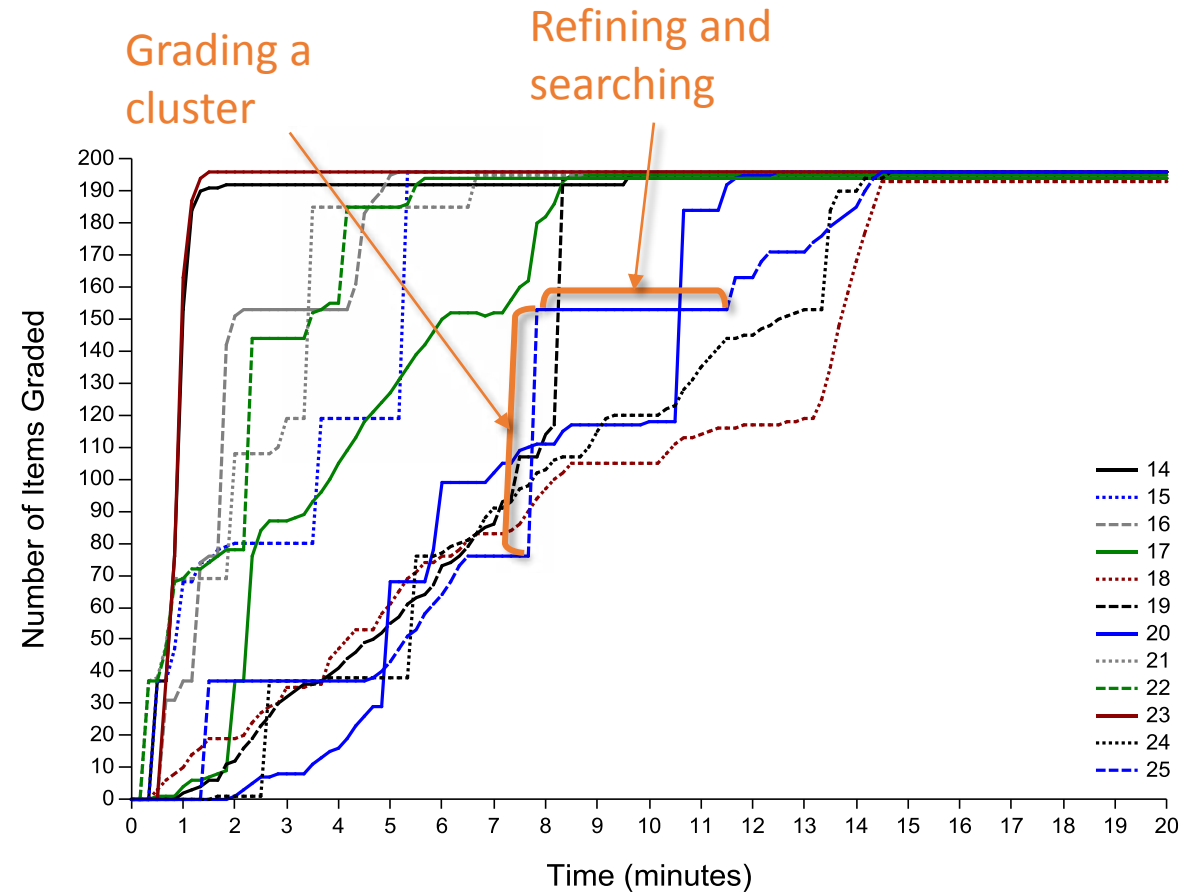


Clustered Interface, answers graded vs. time for Q4

Efficiency

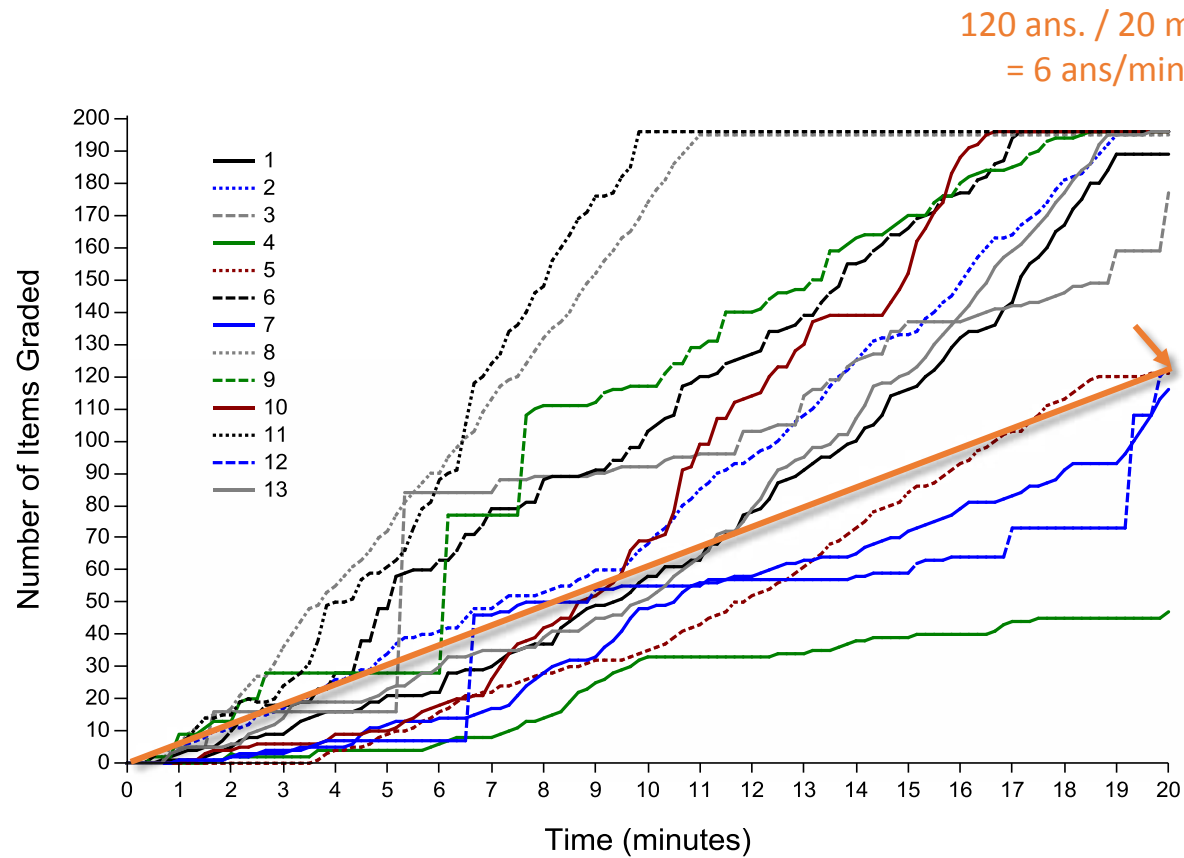


Flat Interface, answers graded vs. time for Q4

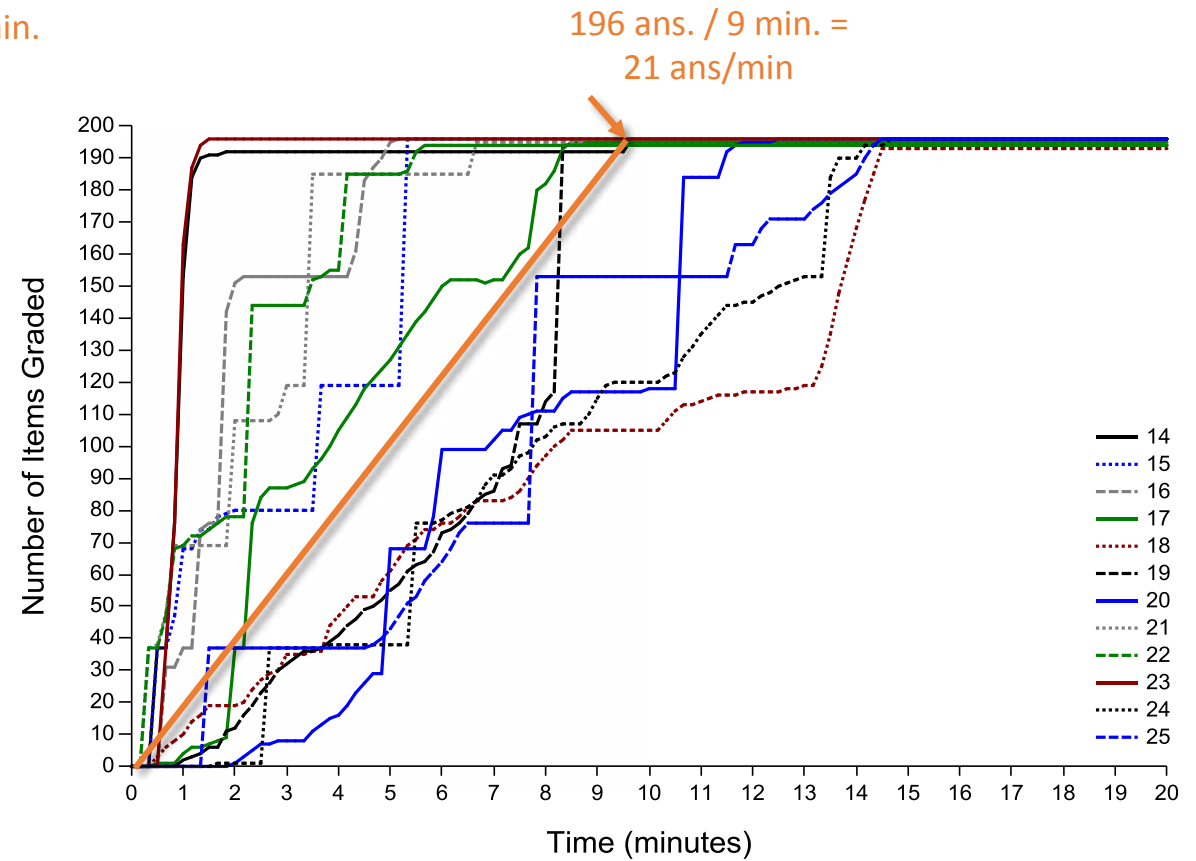


Clustered Interface, answers graded vs. time for Q4

Speed Calculation



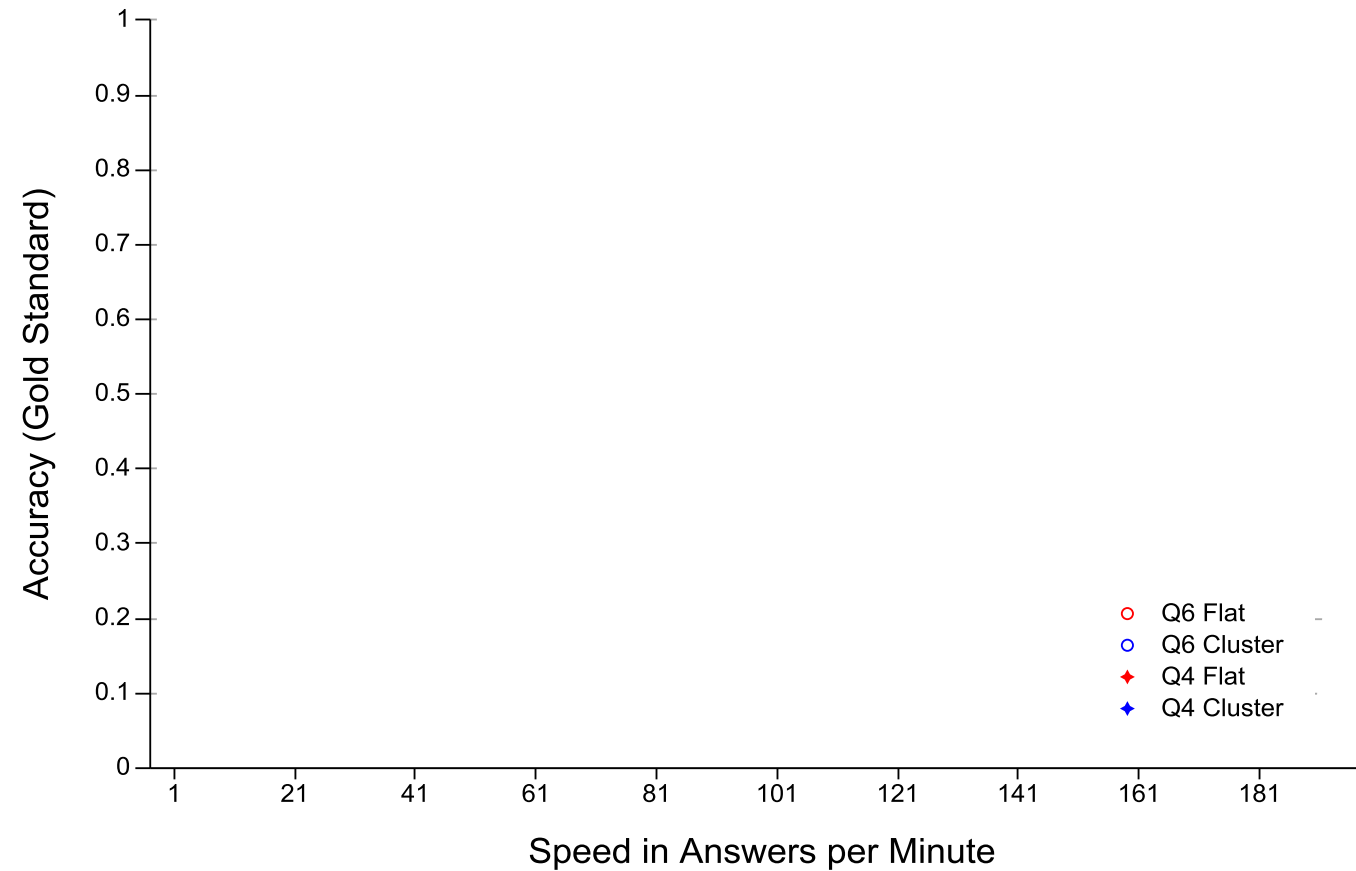
Flat Interface, answers graded vs. time for Q4



Clustered Interface, answers graded vs. time for Q4

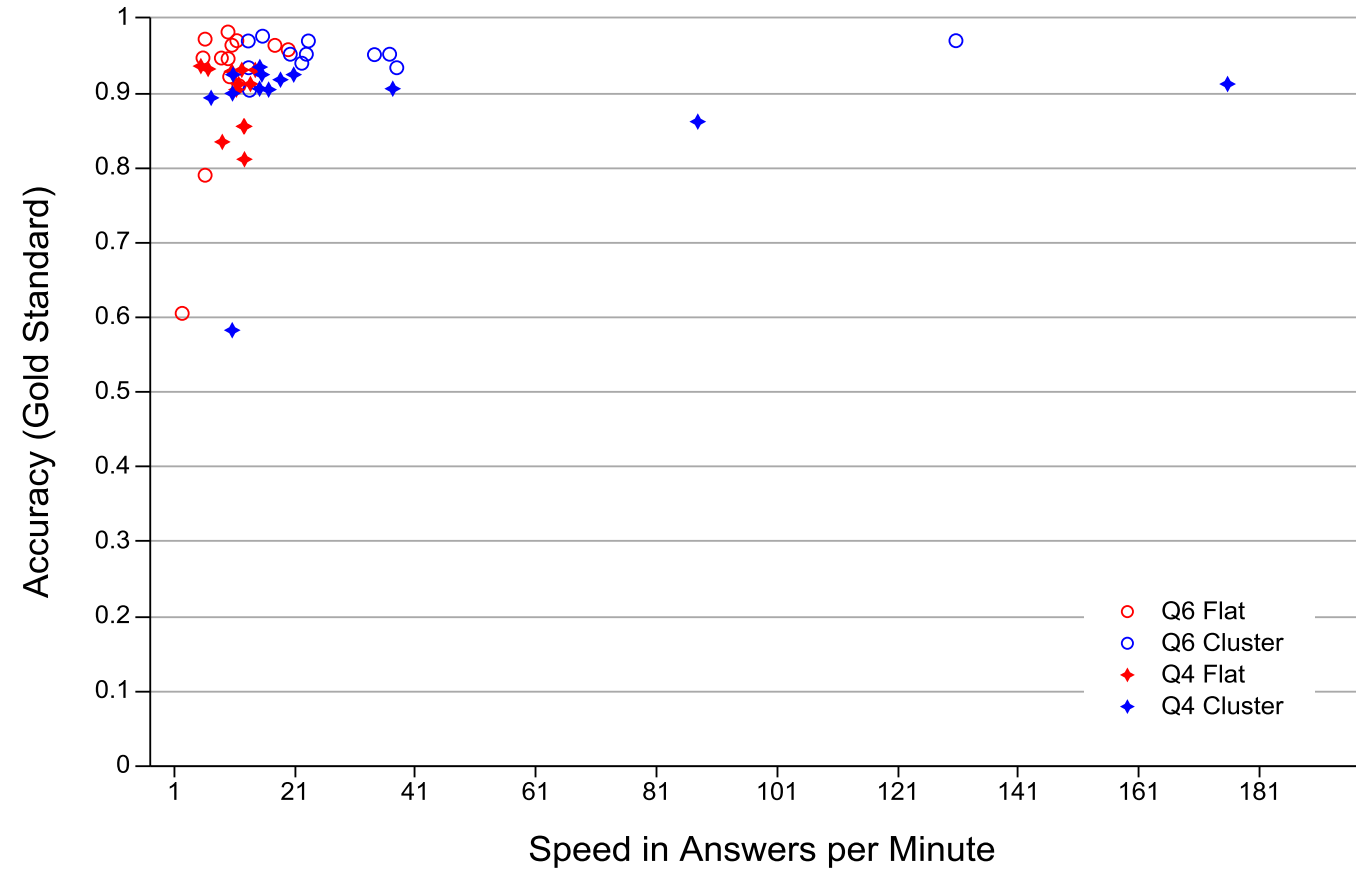
Grading Quality

Accuracy vs. Speed for Both Questions



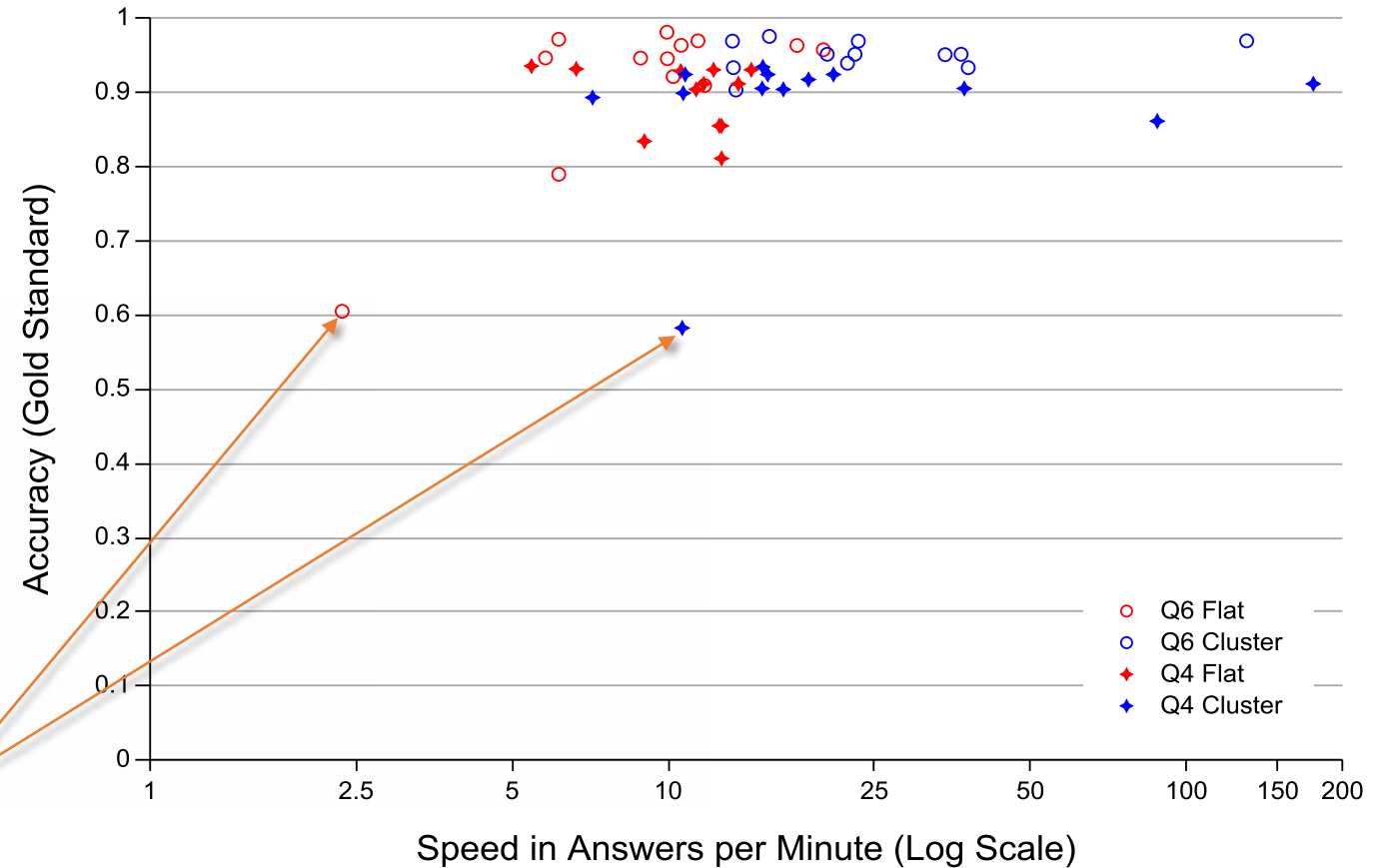
Grading Quality

Accuracy vs. Speed for Both Questions



Grading Quality

Accuracy vs. Speed for Both Questions



Participant 4

Feedback for Students

Question: “Who or what makes federal (national) laws in the US?”

Answer from students Feedback from teachers

“state legislation (legislators)”

“State legislators do not make national laws. The congressional members from the States do, but not the states themselves.”

“congress along with the president
and the supreme court”

“Be clear with your response. what role if any does the Supreme Court play?”

Amplifying Feedback

- No difference in median amount of feedback written
- Clustering distributed feedback to more answers (median 75 vs. 18)
- Clustered interface rated higher for supporting feedback

“Being able to grade categorized responses makes it easier on the grader and allows them to pay closer attention to types of feedback needed.” (P24)

“Because [the clustered interface] was so much faster, more time could be spent giving feedback.” (P14)

Instructor Reflection

- Insights elicited after grading appeared equally rich
- Participants felt the clustered interface was better for this:

*“This interface does make **answer trends more easily identifiable.**” (P6)*

*“I liked this [clustered] interface better; breaking the answers down into clusters allowed me to **spot patterns**, to **be more consistent** in grading, and to **devote more time to individual answers** where it wasn't clear whether they were right or wrong. The information seemed less overwhelming when presented this way, so I felt like I was less apt to mis-read or mis-grade any one answer.” (P8)*

Findings

Preferences: Faster, easier to use, more enjoyable and effective

Efficiency: Makes rapid grading possible

Quality: Effectively allows the grader to control quality

Feedback: Impact of feedback increased

Reflection: Clustering aids reflection

Conclusions

- Clustered grading of short answers is promising
 - More scalable grading without loss of accuracy
 - Better support for feedback and instructor reflection
- Future work
 - Evaluation at larger scale, in a real course
 - Refinement to clustering, visual cluster summaries
 - Integrate auto-grading features

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Backup Slides

Clusters

x378 congress
congress us makes house senate federal laws

x103 legislative branch
legislative legislative executive writes branch legislation legislators senate congress judicial laws branches

x81 senate and house of representatives
combination congress legislative vote branch composed us house government senate united legislature representatives representatives veto senators president u s laws proposed

x53 [miscellaneous]
supreme legislature executive federal us court people laws

x27 president, congress
legislative combination along branch passes corporations signs president presidential order can supreme veto signed sign court special effect interest groups law laws bill sent pass president's people favors senate members

Subclusters

x369 congress
congress us makes laws

x4 house of congress
congress house

x4 congress and senate
congress senate

x1 congress is in charge of making federal laws.

Answers

x333 congress

x14 congress.

x3 congress?

x5 the congress

x2 the congress.

x1 congress makes laws

x5 us congress

x1 congress makes the federal laws

x1 congress votes

x1 congress or house

x1 house of congress

x1 the us congress

x1 the u.s. congress.

x1 congress and the house

x1 the house and congress

x1 congress proposes laws

x1 congress or senate

x2 congress and senate

1 cluster selected
Mark Unread Flag

Grading
Incorrect Partial Correct

Feedback
Clear Save

Answer Key
Q: Who or what makes federal (national) laws in the US?

- Congress
- Senate and House
- Senate and House of Representatives

Clusters

x378 congress
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Subclusters
<p>x40 congress (senate and house of representatives)</p> <p>congress vote senate house legislature representatives senators president laws proposed</p>
<p>x16 senate</p> <p>senate</p>
<p>x13 house and senate</p> <p>us house senate</p>
<p>x12 the legislative branch (house of representatives and the senate)</p> <p>legislative congress branch composed government house president representatives senate u s</p>

Answers
x1 senate and house of representatives
x1 the senate and house of representatives
x2 senate and the house of representatives
x1 the senate and house of representatives.
x1 the senate and the house of representatives
x1 the house of representatives and the senate
x1 the house of representatives, us senate
x1 congress- house of representatives and the senate
x2 congress (senate and house of representatives)
x1 senate and house of representatives (congress)
x1 house of representatives
x1 the senate, house of representatives, the president.
x1 u.s. congress, senate and house of representatives
x1 congress (the senate and the house of representatives)
x1 house of the representatives
x4 the house of representatives
x1 house of representatives.
x4 house and senate
x1 senate and house of representatives with presidents approval
x1 senate,house representives
x1 senate and house of representatives
x1 the house and senate
x1 congress which is made up of the house of representatives and the senate.
x2 the legislative branch (house of representatives and the senate)
x1 the legislative branch, i.e. house of representatives and the senate

1 cluster selected

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Incorrect Partial Correct

Feedback Clear Save

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Answers

x9 senate

x1 senate?

x5 the senate

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both houses of congress are involved; not just the Senate.

Copy previous feedback:

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Answers

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both houses of cong...

x1 senate?
both houses of cong...

x5 the senate
both houses of cong...

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