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

Michael Brooks[1,2], Sumit Basu[1], Chuck Jacobs[1], Lucy Vanderwende[1]

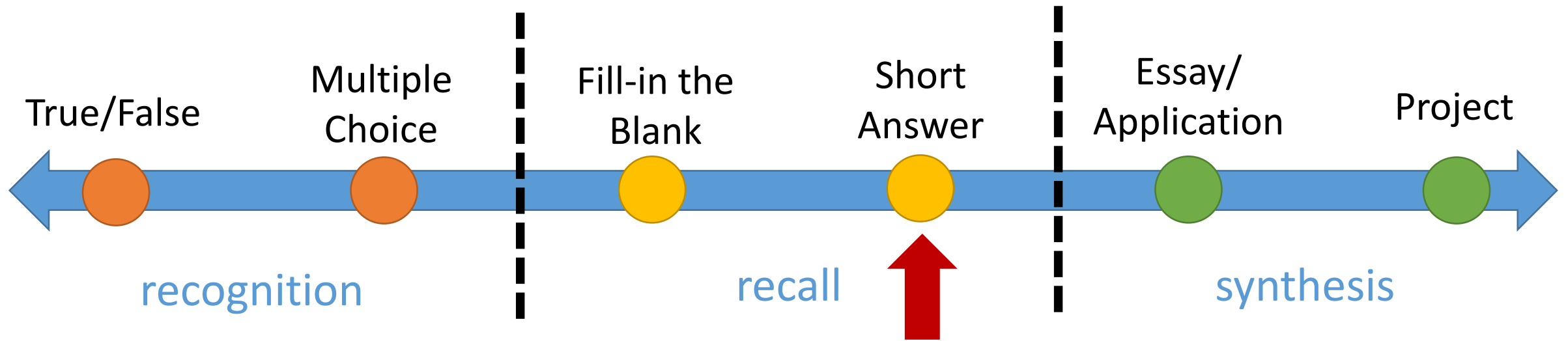Learning At Scale 2014: Assessment

March 5th, 2014, Atlanta

Microsoft Research

UNIVERSITY of WASHINGTON

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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

McMillan, 2001. Secondary Teachers' Classroom Assessment and Grading Practices.

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

- Peer Grading
  - Debiasing and aggregation
  - Crowdsourced grading
  - Possible learning benefits

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

Leacock & Chodorow 2003

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

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

Weld, Adar & Chilton 2012

Sadler & Good 2006

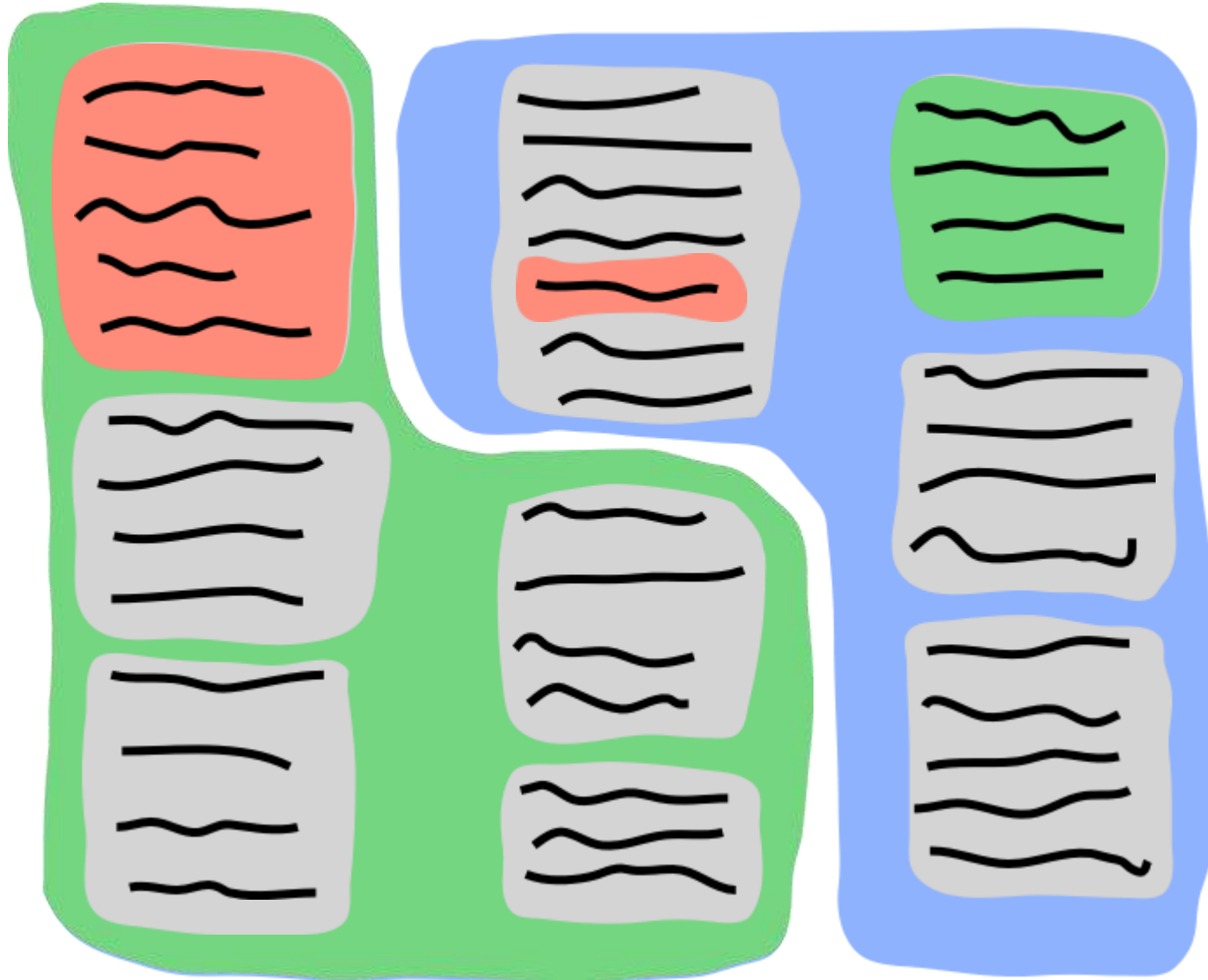# Our Approach: Divide and Correct

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

Clustered Grading Interface Design

- Exploratory navigation
- Grade and feedback is inherited and overridden

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 represenatives representatives veto senators president u s laws proposed

words contained in answers

19:47   Grading   Feedback

Clusters

x378 **congress**

congress us makes house senate federal laws

x103 **legislative branch**

legistlative **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**

Subclusters

← Select a cluster to start

Answers

see http://bit.ly/powergrading

Nothing selected

Mark Read   ❶ 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)

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

	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
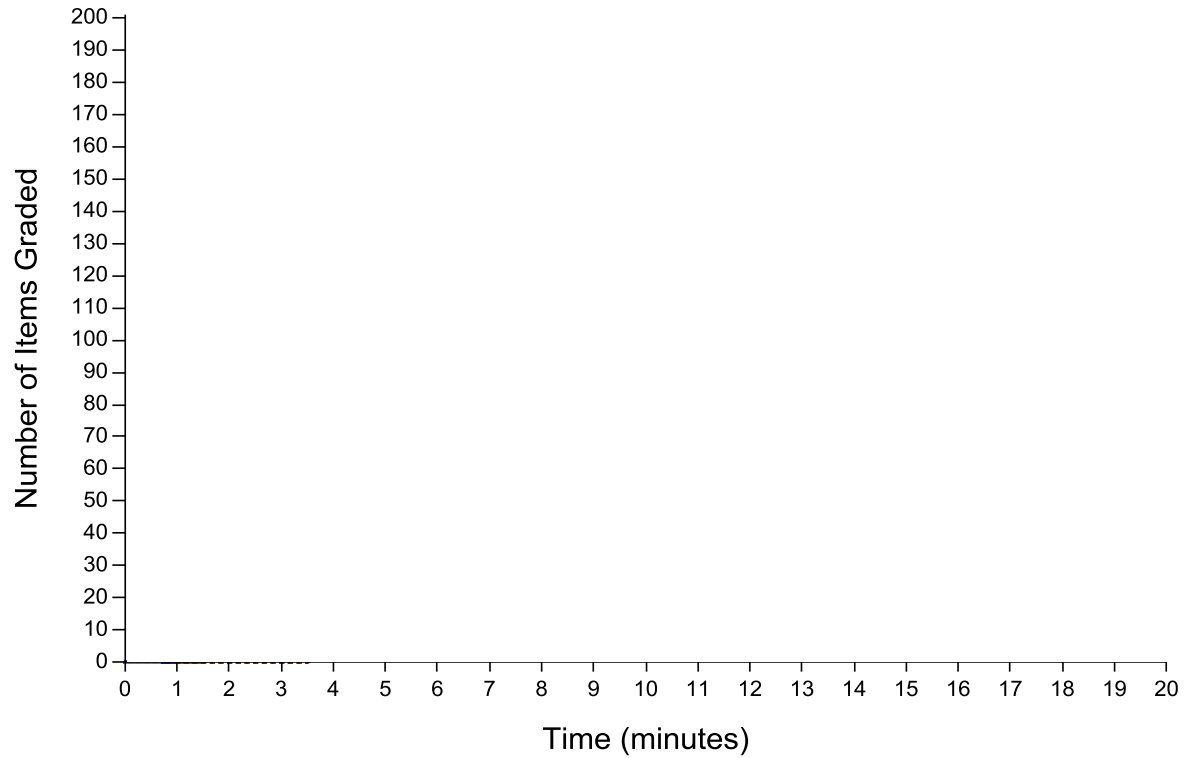
Flat Interface, answers graded vs. time for Q4
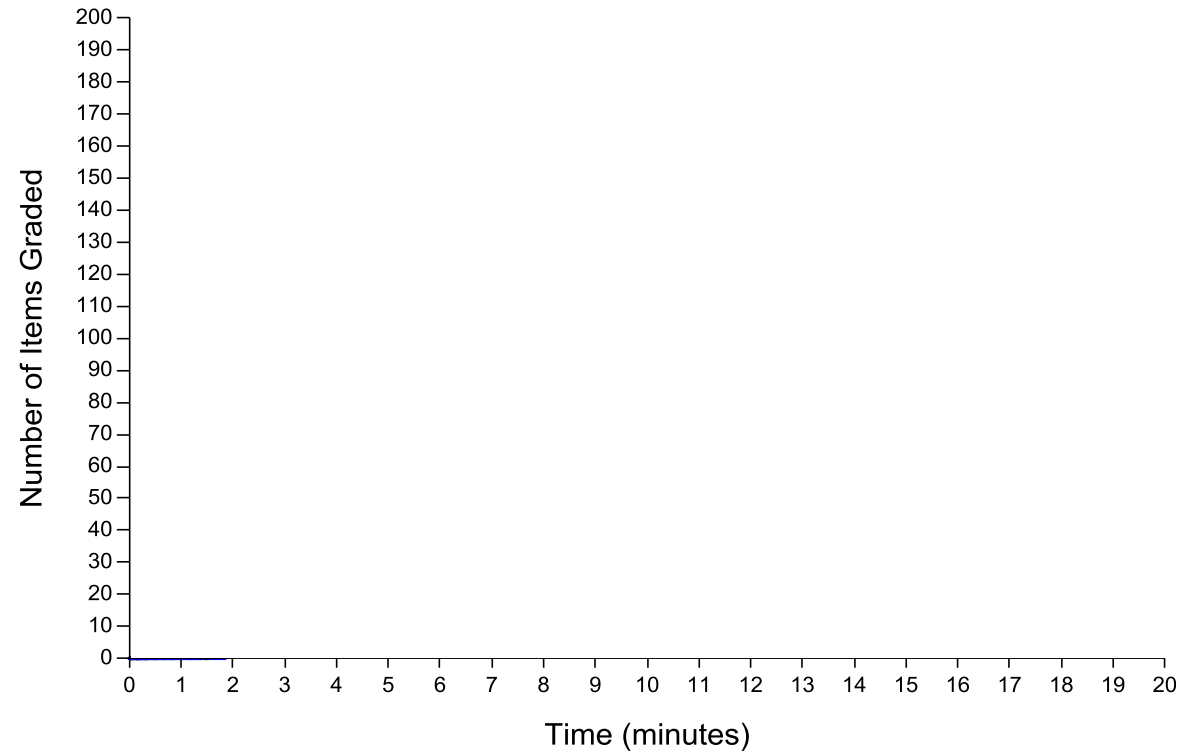
Clustered Interface, answers graded vs. time for Q4

Efficiency
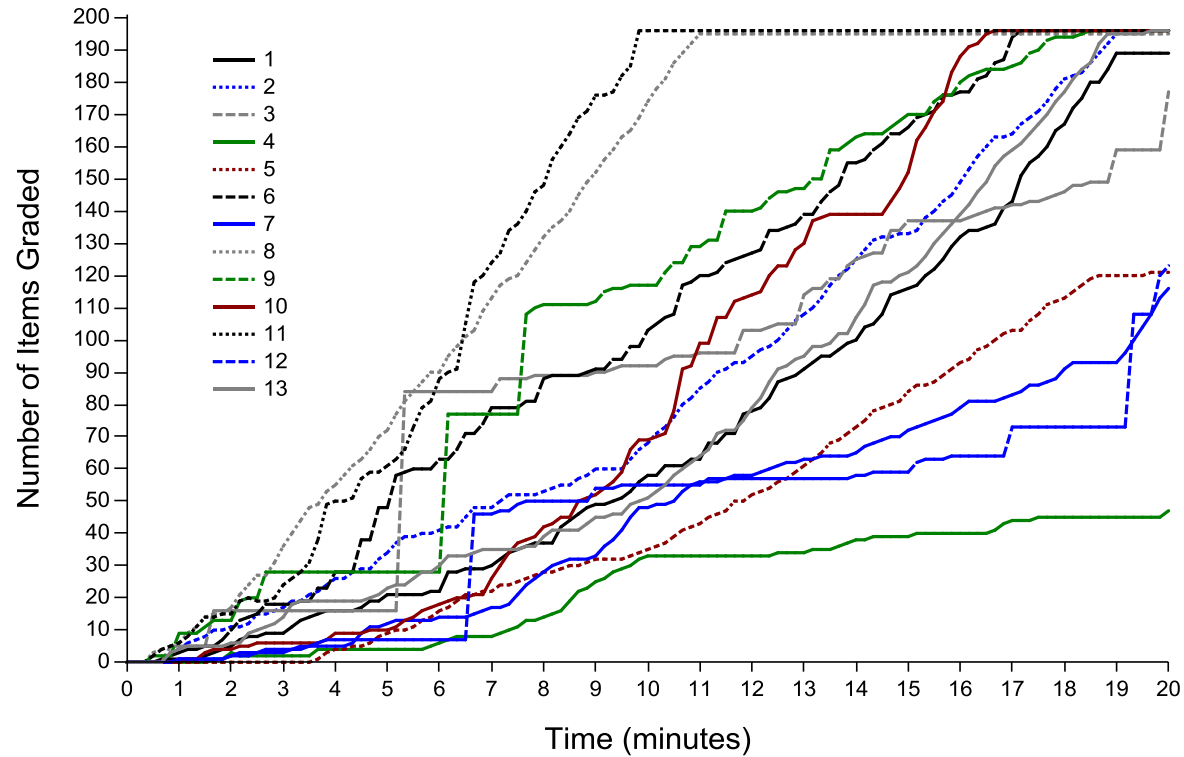
Flat Interface, answers graded vs. time for Q4
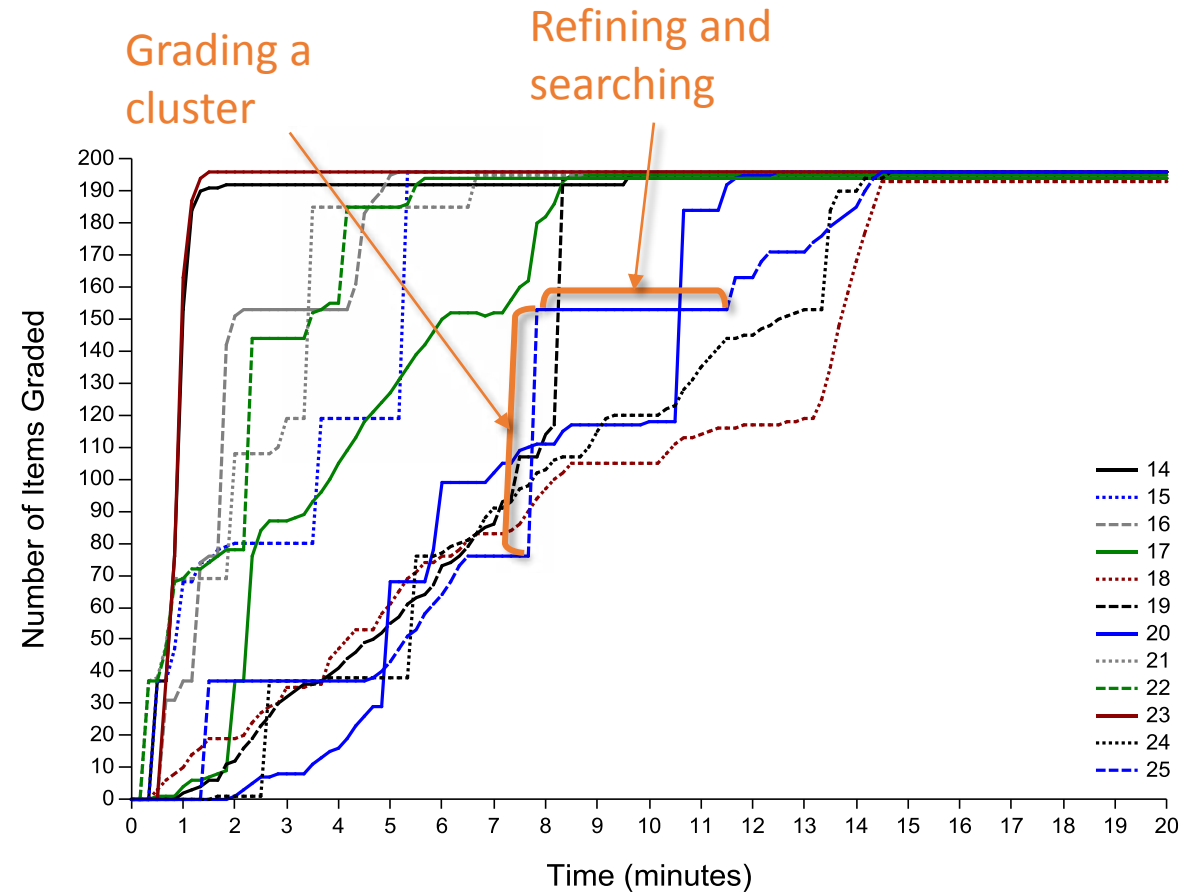
Clustered Interface, answers graded vs. time for Q4

Speed Calculation
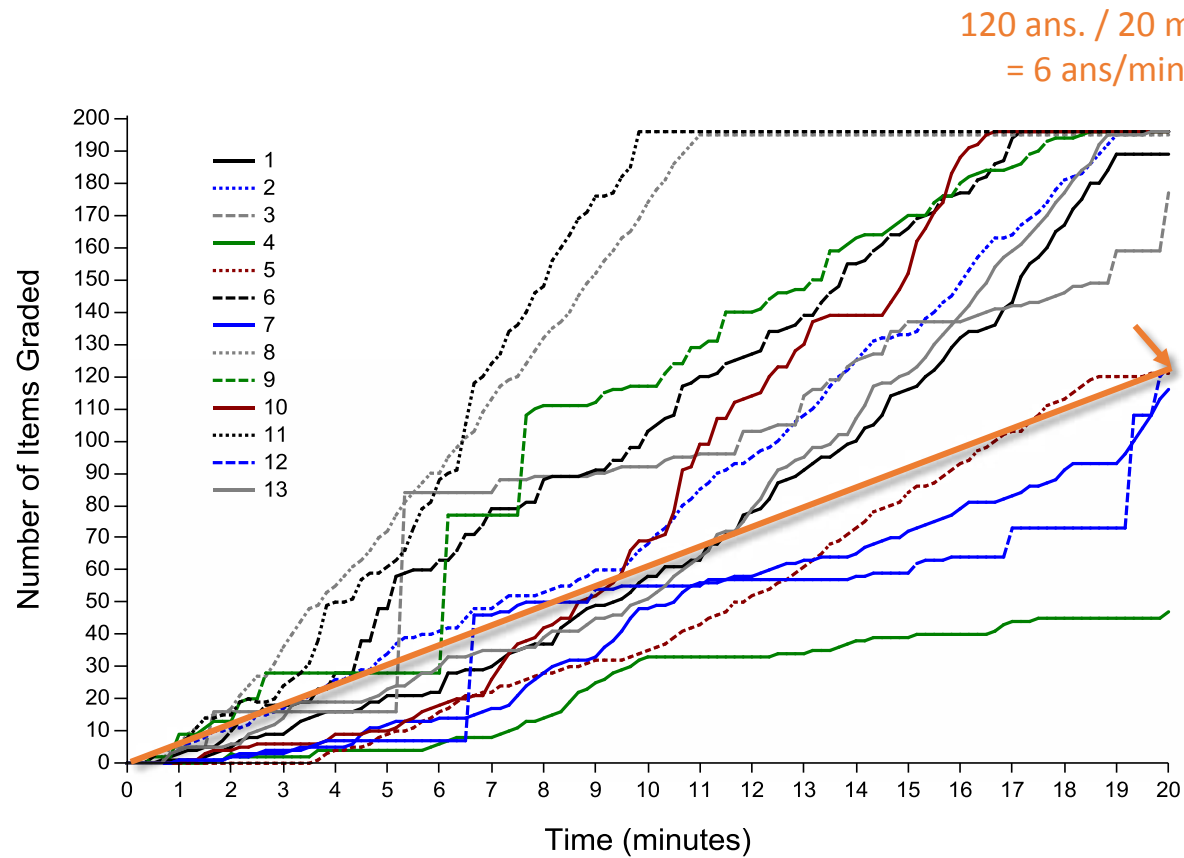
120 ans. / 20 min. = 6 ans/min

196 ans. / 9 min. = 21 ans/min

Flat Interface, answers graded vs. time for Q4
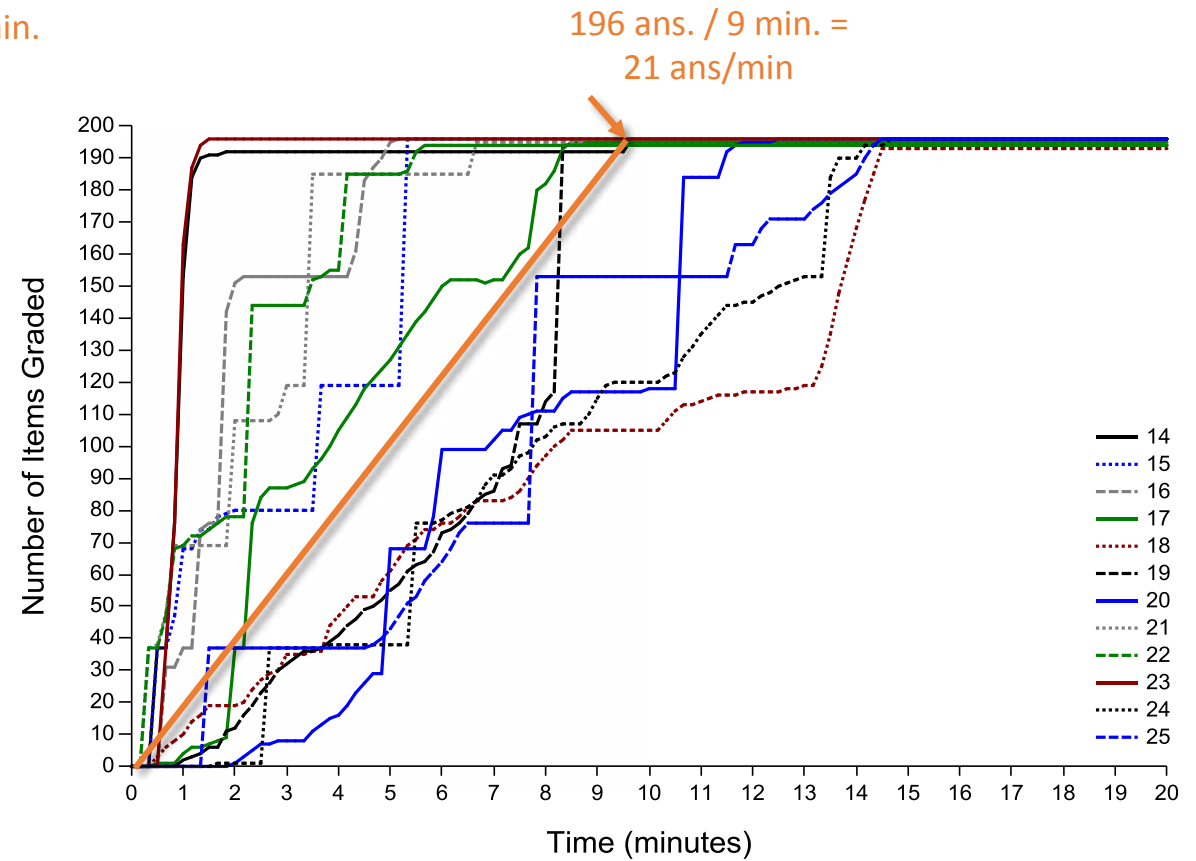
Clustered Interface, answers graded vs. time for Q4

Grading Quality

Accuracy vs. Speed for Both Questions
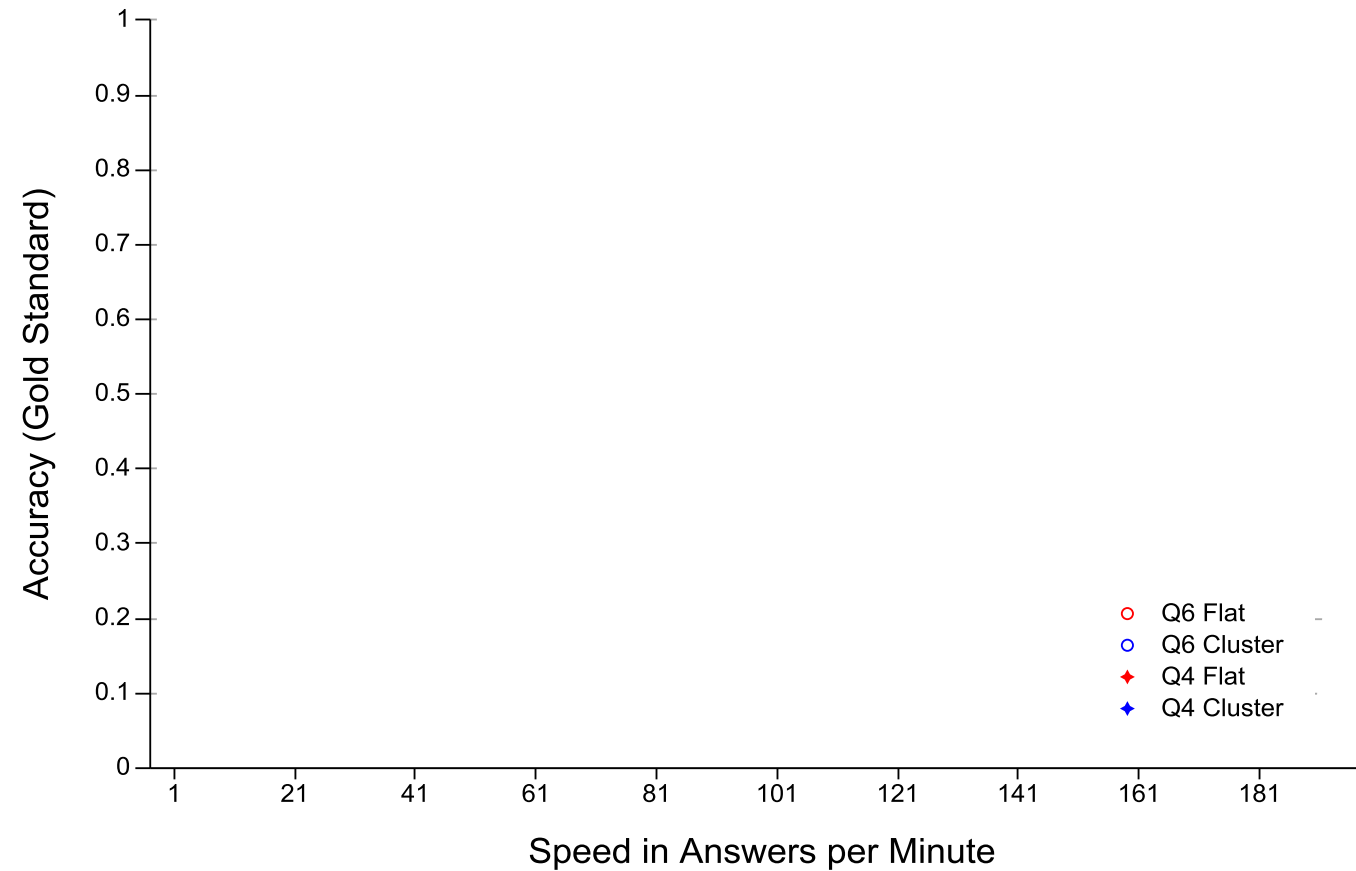
Grading Quality

Accuracy vs. Speed for Both Questions
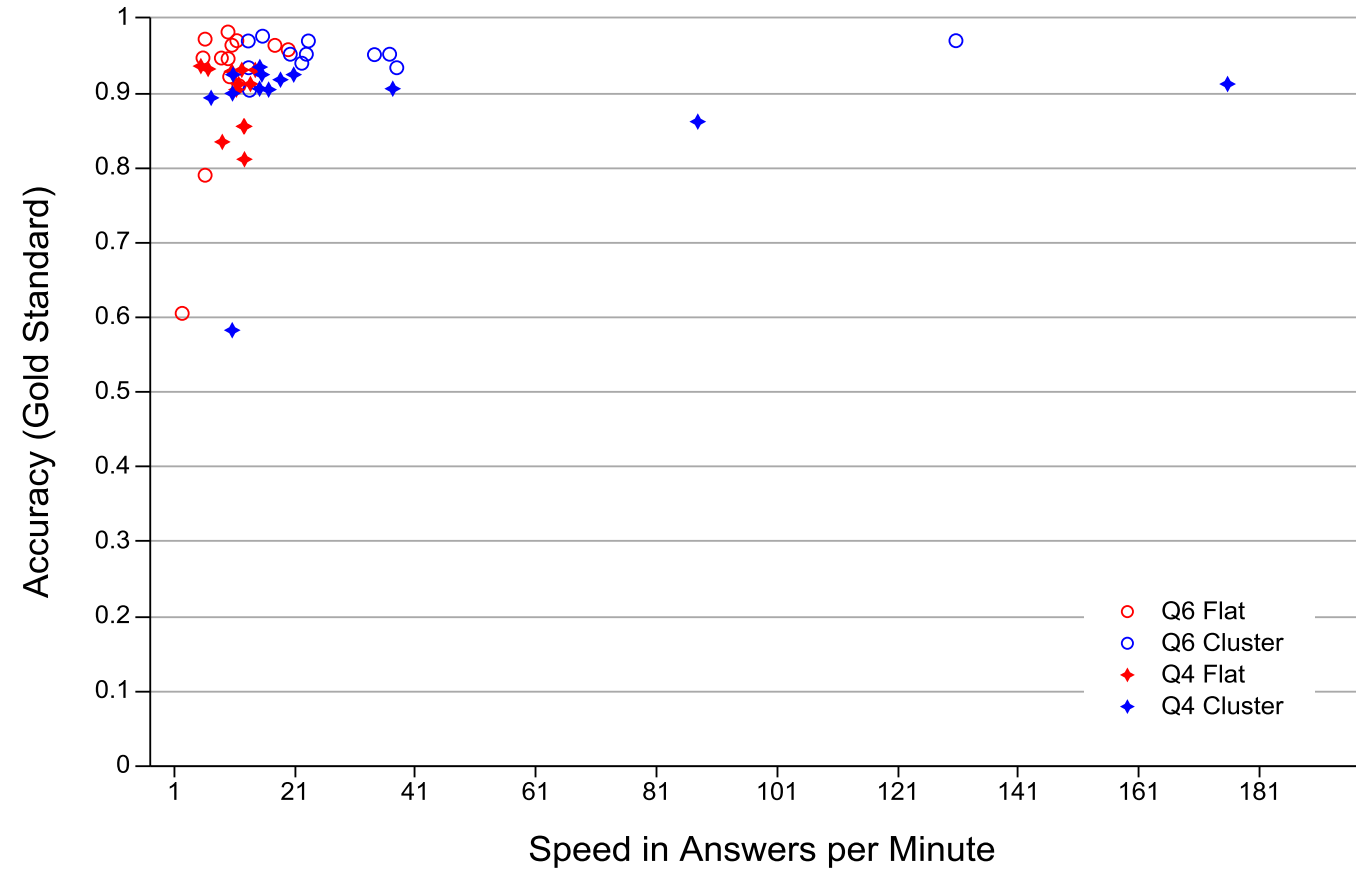
Grading Quality

Accuracy vs. Speed for Both Questions
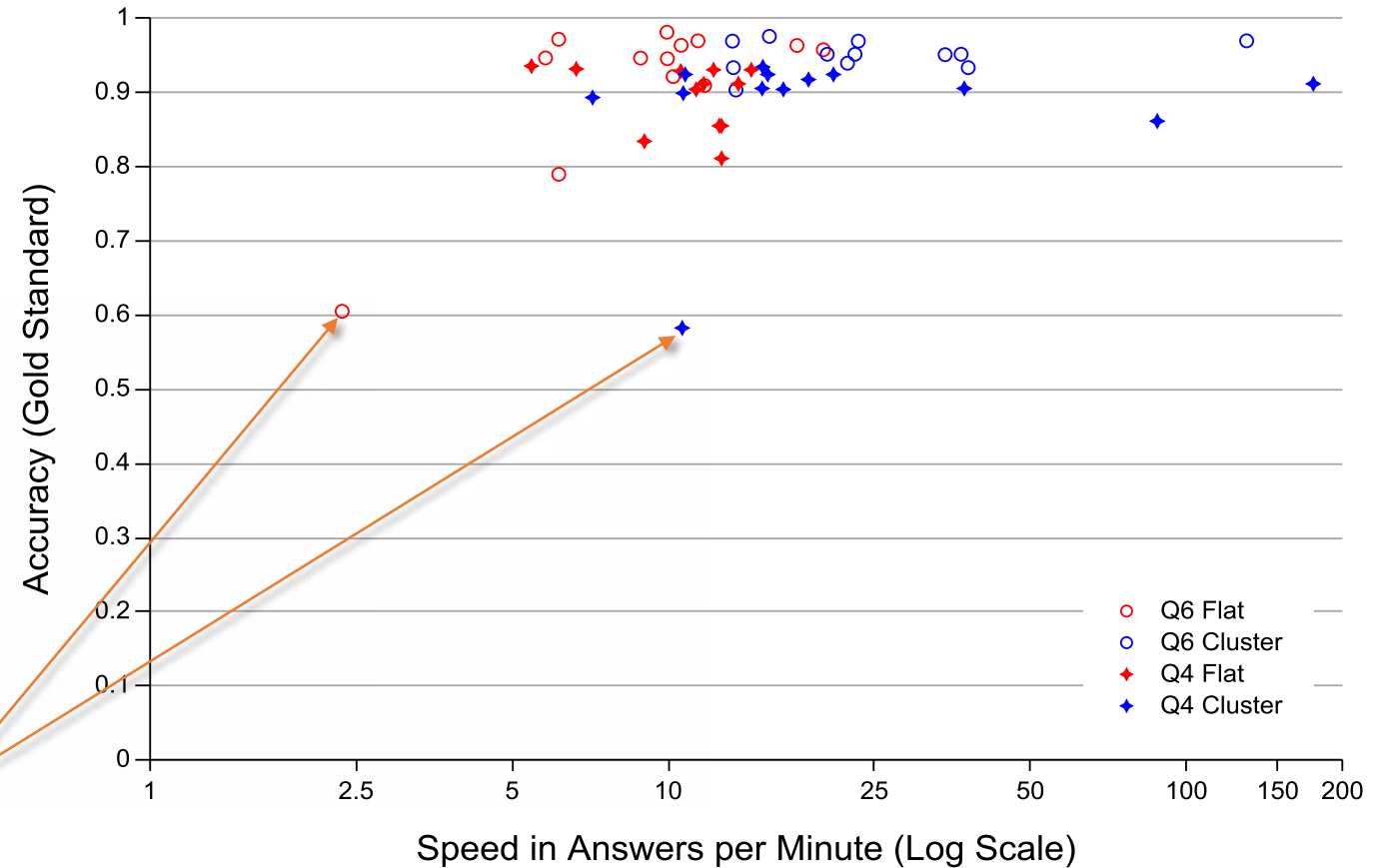
Feedback for Students

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

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

19:06   Grading [   ]   Feedback [   ]

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 represenatives 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

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

18:22   Grading   Feedback

Clusters

x378 congress

congress us makes house senate federal laws

x103 legislative branch

legistlative 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 represenatives 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

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

17:48   Grading   Feedback

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 represenatives 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

Subclusters

x40 congress (senate and house of representatives)

congress vote senate house legislature representatives senators president laws proposed

x16 senate

senate

x13 house and senate

us house senate

x12 the legislative branch (house of representatives and the senate)

legislative congress branch composed government house president representatives senate u s

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 represevtives
x1	senate and house of represenatives
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

Mark Unread   ❗ Flag

Grading

Incorrect   Partial   Correct

Feedback   Clear   Save

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

Congress

Senate and House

Senate and House of Representatives

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

17:26   Grading ▰▰▰▰▱   Feedback ▱▱▱▱▱

Clusters

x378 congress

congress us makes house senate federal laws

x103 legislative branch

legistlative **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 represenatives 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

Subclusters

x40 congress (senate and house of representatives)

congress vote senate house legislature representatives senators president laws proposed

x16 senate

senate

x13 house and senate

us house senate

x12 the legislative branch (house of representatives and the senate)

legislative congress branch composed government house president representatives senate u s

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 represevtives
x1	senate and house of represenatives
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

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

17:01   Grading   Feedback

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 represenatives **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

Subclusters

x40	**congress (senate and house of representatives)**

congress vote senate house legislature representatives senators president laws proposed

x16	senate

senate

x13	**house and senate**

us house senate

x12	**the legislative branch (house of representatives and the senate)**

legislative congress branch composed government house president representatives senate u s

Answers

x9	senate
x1	senate?
x5	the senate
x1	the senate?

1 subcluster 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

16:49   Grading   Feedback

Clusters

| x378 | congress |

congress us makes house senate federal laws

| x103 | legislative branch |

legistlative **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 represenatives **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

Subclusters

| x40 | congress (senate and house of representatives) |

congress vote **senate** **house** legislature representatives senators president laws proposed

| x16 | senate |

senate

| x13 | house and senate |

us house senate

| x12 | the legislative branch (house of representatives and the senate) |

legislative congress branch composed government **house** president representatives senate u s

Answers

x9	senate
x1	senate?
x5	the senate
x1	the senate?

1 subcluster 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

16:16   Grading ▨▨▨   Feedback ▭

Clusters

x378 congress

congress us makes house senate federal laws

x103 legislative branch

legistlative **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 represenatives **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

Subclusters

x40 congress (senate and house of representatives)

congress vote senate house legislature representatives senators president laws proposed

x16 senate

senate

x13 house and senate

us house senate

x12 the legislative branch (house of representatives and the senate)

legislative congress branch composed government house president representatives senate u s

Answers

x9   senate

x1   senate?

x5   the senate

x1   the senate?

---

1 subcluster selected

Mark Unread   ❗ Flag

Grading

Incorrect | Partial | Correct

Feedback   Clear   Save

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

Copy previous feedback:

Answer Key

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

Congress

Senate and House

Senate and House of Representatives

https://powergrading.servicebus.windows.net/pg/grader/index.html#grade/6

Power Grader Prototype

16:00   Grading   Feedback

Clusters

| x378 | congress |

congress us makes house senate federal laws

| x103 | legislative branch |

legistlative **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 represenatives **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

Subclusters

| x40 | congress (senate and house of representatives) | both houses of cong... |

congress vote **senate house** legislature **representatives** senators president laws proposed

| x16 | senate | both houses of cong... |

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

| x13 | house and senate |

us **house senate**

| x12 | the legislative branch (house of representatives and the senate) |

legislative congress branch composed government house president representatives senate u s

Answers

x9	senate	both houses of cong...
x1	senate?	both houses of cong...
x5	the senate	both houses of cong...
x1	the senate?	both houses of cong...

1 subcluster selected

Mark Unread   ❗ Flag

Grading

Incorrect   Partial   Correct

Feedback   Clear   Save

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

Answer Key

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

Congress

Senate and House

Senate and House of Representatives