

# Using implemented grammars in learning to write clearly

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# Goals

- Automated error detection in student writing
- Error-specific recommendations for repair
- High precision and high recall



# Current applications

- Language Arts & Writing course for McGraw-Hill Education  
In U.S. classrooms for past ten years  
50,000 students, primary school, mostly native English  
10 million sentences composed, 1 million short paragraphs  
Two-year efficacy study (Suppes et al 2013)
- On-line test preparation for English as second language  
In pilot with Beijing education company  
Several hundred students, high school, native Mandarin  
Data collection and error analysis underway



# Exercise design for sentence composition

- Present a few sentences of context
- Ask a question
- Provide a set of (fully inflected) words, listed by part-of-speech
- Ask the student to compose an answer as a complete sentence
- Evaluate the answer, and if incorrect, identify error where possible
- Invite the student to try again once



# An example from an early grade

🔊 When the worker reaches the well, he climbs down into it.

🔊 Which way does the worker go?

## Adverb

down  
left  
up

## Article

the

## Noun

Grace  
well  
worker

## Preposition

down  
into  
up

## Pronoun

he  
him  
them

## Verb

goes  
going

Type your answer here

On-line sampler of course materials:

[mheducation.com/prek-12/explore/redbird/language-arts-writing.html](http://mheducation.com/prek-12/explore/redbird/language-arts-writing.html)



# An example from an early grade

- When the worker reaches the well, he climbs down into it.
- Which way does the worker go?

**Adverb**  
down  
left  
up

**Article**  
the

**Noun**  
Grace  
well  
worker

**Preposition**  
down  
into  
up

**Pronoun**  
he  
him  
them

**Verb**  
goes  
going

Him goes down into the well

Don't use "him" here. Instead, use the subject pronoun "he", or a noun phrase like "John" or "the book". Correct any mistakes, and add a period at the end of the sentence again.



# An example from an early grade

🔊 When the worker reaches the well, he climbs down into it.

🔊 Which way does the worker go?

**Adverb**  
down  
left  
up

**Article**  
the

**Noun**  
Grace  
well  
worker

**Preposition**  
down  
into  
up

**Pronoun**  
he  
him  
them

**Verb**  
goes  
going

The worker goes down into the well.

Good job!



## Another example from an early grade

*Colin and Miguel enjoy eating spaghetti with meat sauce.  
What do Colin and Miguel like to eat?*

Student answer: **They like eat spaghetti.**

System response: *You are missing the word “to” before “eat”.*





## An example from a later grade

*Abigail didn't want to go hiking with her parents because she felt too tired and wanted to rest instead.*

*Why didn't Abigail want to go hiking?*



## An example from a later grade

*Abigail didn't want to go hiking with her parents because she felt too tired and wanted to rest instead.  
Why didn't Abigail want to go hiking?*

She was tired.



## An example from a later grade

*Abigail didn't want to go hiking with her parents because she felt too tired and wanted to rest instead.  
Why didn't Abigail want to go hiking?*

She was tired.

She was too tired.



## An example from a later grade

*Abigail didn't want to go hiking with her parents because she felt too tired and wanted to rest instead.  
Why didn't Abigail want to go hiking?*

She was tired.

She was too tired.

She was too tired to.



## An example from a later grade

*Abigail didn't want to go hiking with her parents because she felt too tired and wanted to rest instead.  
Why didn't Abigail want to go hiking?*

She was tired.

She was too tired.

She was too tired to.

She was too tired to go.



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She was too tired to.

She was too tired to go.

She was too tired to hike.



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She was too tired to go hike.

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She was too tired.

She was too tired to.

She was too tired to go.

She was too tired to hike.

She was too tired to go hike.

She was too tired to go hiking.

She didn't because she was too tired.





## An example from a later grade

*Abigail didn't want to go hiking with her parents because she felt too tired and wanted to rest instead.  
Why didn't Abigail want to go hiking?*

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She was too tired to.

She was too tired to go.

She was too tired to hike.

She was too tired to go hike.

She was too tired to go hiking.

She didn't because she was too tired.

She didn't want to because she was too tired.



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She was too tired to go hike.

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*Abigail didn't want to go hiking with her parents because she felt too tired and wanted to rest instead.  
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She was too tired to go hiking.

She didn't because she was too tired.

She didn't want to because she was too tired.

She didn't want to go because she was too tired.

She didn't want to hike because she was too tired.



## An example from a later grade

*Abigail didn't want to go hiking with her parents because she felt too tired and wanted to rest instead.*

*Why didn't Abigail want to go hiking?*

She was tired.

She was too tired.

She was too tired to.

She was too tired to go.

She was too tired to hike.

She was too tired to go hike.

She was too tired to go hiking.

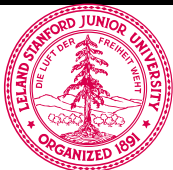
She didn't because she was too tired.

She didn't want to because she was too tired.

She didn't want to go because she was too tired.

She didn't want to hike because she was too tired.

She didn't want to go hike because she was too tired..



## An example from a later grade

*Abigail didn't want to go hiking with her parents because she felt too tired and wanted to rest instead.*  
*Why didn't Abigail want to go hiking?*

She was tired.

She was too tired.

She was too tired to.

She was too tired to go.

She was too tired to hike.

She was too tired to go hike.

She was too tired to go hiking.

She didn't because she was too tired.

She didn't want to because she was too tired.

She didn't want to go because she was too tired.

She didn't want to hike because she was too tired.

She didn't want to go hike because she was too tired..

She didn't want to go hiking because she was too tired.



# More variants

She **didn't** because she was tired.  
She didn't because she was too tired to.  
She didn't because she was too tired to go.  
She didn't because she was too tired to go hike.  
She didn't because she was too tired to go hiking.  
She didn't because she was too tired to hike.  
She didn't **want to** because she was tired.  
She didn't want to because she was too tired to.  
She didn't want to because she was too tired to go.  
She didn't want to because she was too tired to go hike.  
She didn't want to because she was too tired to go hiking.  
She didn't want to because she was too tired to hike.  
She didn't **want to go** because she was tired.  
She didn't want to go because she was too tired to.  
She didn't want to go because she was too tired to hike.  
She didn't want to go because she was too tired to go hike.  
She didn't want to go because she was too tired to go hiking.  
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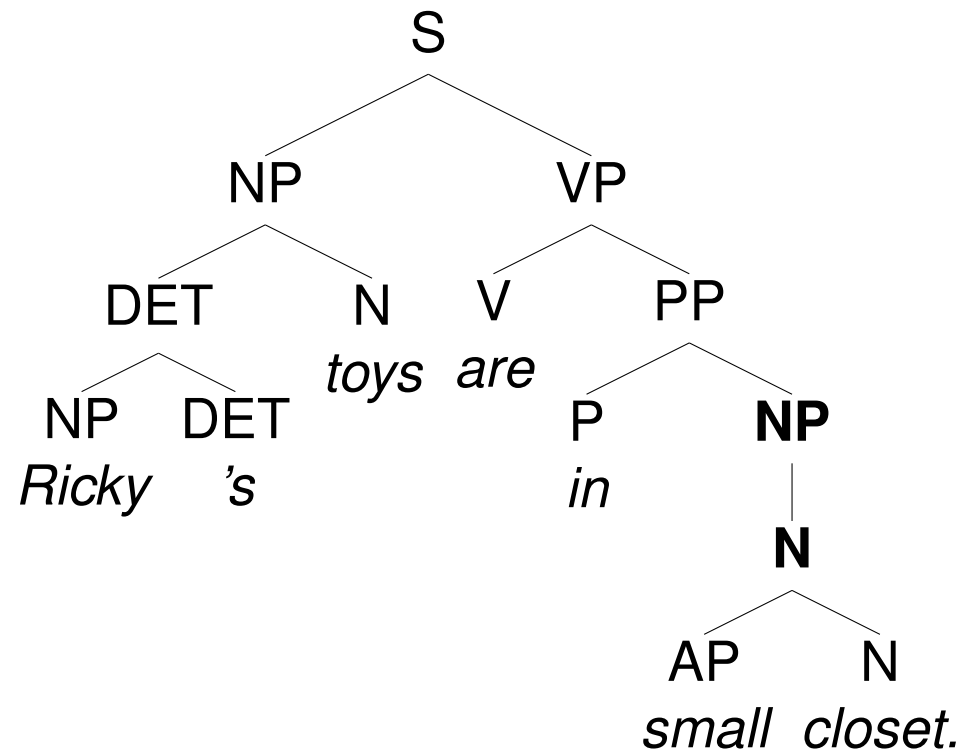
# Approach

- Use existing DELPH-IN resources ([www.delph-in.net](http://www.delph-in.net))
  - English Resource Grammar (ERG: Flickinger 2000, 2011)
  - Efficient ACE parser ([moin.delph-in.net/AceTop](http://moin.delph-in.net/AceTop))
- Adapt ‘mal-rule’ approach to accept mild ungrammaticality
  - Schneider & McCoy (1998), Bender et al. (2004)
- Parse each novel input and return derivation tree
- Check for `root_robust`, and if so, find `..._rbst` node
- Look up robustness symbol in error code table (grade-specific)
- Present appropriate message to student



# An ungrammatical example

*Ricky's toys are in small closet.*



# Theoretical linguistic framework: HPSG

## Head-driven Phrase Structure Grammar

- Sign-based view of words and phrases as feature structures
- Constraints on morphology, syntax, and semantics
- Rich lexicon, small number of schematic rules
- Principles for propagation of feature values within phrases
- Growing emphasis on constructions
- Analyses valid for both parsing and generation



# Theoretical linguistic framework: HPSG

## Head-driven Phrase Structure Grammar

- Sign-based view of words and phrases as feature structures
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- Growing emphasis on constructions
- Analyses valid for both parsing and generation

## Typed feature structures

- Hierarchy of types with appropriate features
- Cross-classification via multiple inheritance
- Merging of constraints via unification



# English Resource Grammar (ERG)

- 7000 types in multiple-inheritance monotonic hierarchy
- 1000 leaf lexical types
- 40,000 manually constructed lexemes
- 200 syntactic rules
- 100 morphological rules (inflection and derivation)
- Online demo: `lingo.stanford.edu/erg`



# Changes to the general-purpose grammar

## Extensions to permit common errors

- **Mal-rules** for inflection, syntax  
e.g. bare singular NP, or bare 3sg-present verb
- **Mal-types** for lexicon  
e.g. subj-equi with base VP: *\*Ricky likes go to the park*



# Changes to the general-purpose grammar

## Extensions to permit common errors

- **Mal-rules** for inflection, syntax  
e.g. bare singular NP, or bare 3sg-present verb
- **Mal-types** for lexicon  
e.g. subj-equi with base VP: *\*Ricky likes go to the park*

## Reductions to avoid some ambiguity

- Rules  
For example, block some noun-noun compounds  
*\*Ricky's **closet toys** are in the closet*
- Lexicon  
For example, block the verb *flower*  
*Art and science **flowered** during the 17th century.*



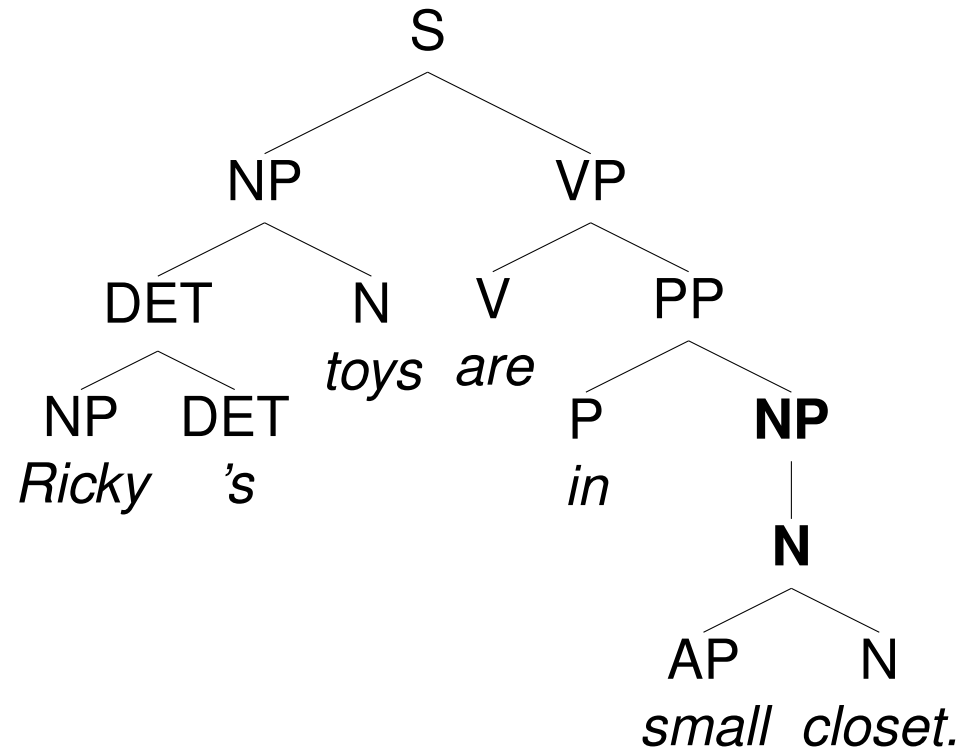


# Example derivation

```
(sb-hd_mc_c [root_robust_s]
  (sp-hd_n_c
    (sp-hd_hc_c
      (hdn_bnp-pn_c
        (n_sg_ilr (ricky_n1/n_-_pn_le ("ricky" <0:1>))))
        (apostrophe_s_2_lex/n_-_cl-poss_le ("'s" <1:2>)))
        (n_pl_olr (toy_n1/n_-_c_le ("toys" <2:3>))))
      (hd-cmp_u_c
        (be_c_are/v_prd_are_le ("are" <3:4>))
        (hd-cmp_u_c
          (in/p_np_i-reg_le ("in" <4:5>))
          ( bare_np_sg_rbst
            (n_sg_ilr (closet_n1/n_-_c_le ("closet" <5:6>))))))))))
```



# Mal-rule example: bare\_np\_sg\_rbst



HEAD	<i>noun</i>								
SPR	< >								
DTR	<table border="1"> <tr> <td>SPR</td> <td>&lt; [OPT -] &gt;</td> </tr> <tr> <td>AGR</td> <td> <table border="1"> <tr> <td>PN</td> <td>3sing</td> </tr> <tr> <td>DIV</td> <td>-</td> </tr> </table> </td> </tr> </table>	SPR	< [OPT -] >	AGR	<table border="1"> <tr> <td>PN</td> <td>3sing</td> </tr> <tr> <td>DIV</td> <td>-</td> </tr> </table>	PN	3sing	DIV	-
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PN	3sing								
DIV	-								



# Sample error messages

Your answer is not grammatical.  
Your answer is not a complete sentence.  
Your answer is grammatical but awkward.  
Your answer cannot be a question.  
You are missing an article before the word \$X.  
Remember to use "an" only before a vowel.  
Don't use "a" before a vowel.  
Don't put "the" before a name.  
You are missing a preposition before \$X.  
You are missing the word "to" before \$X.  
Don't put "to" before \$X.  
The verb \$X needs an object.  
You are missing a noun.  
Use an adverb such as "well" instead of "good".  
Use "its" instead of "it's" to show ownership.  
Remember to use "this" only before a singular noun.  
Don't use "did/does/do" in your answer.  
You have the wrong form of the verb "be".  
Your subject doesn't agree with the verb \$X.

*He are be was dog*  
*In the park*  
*They saw in the lake a duck*  
*Did she go to the beach*  
*She went to house*  
*He ate an sandwich*  
*She saw a owl*  
*The Katherine eats breakfast*  
*They watched movies the afternoon*  
*She told her brother borrow her book*  
*She let her brother to borrow her book*  
*She let borrow her book*  
*Our chased the cat*  
*He did good on his test*  
*The dog is in it's house*  
*He said he like this mittens*  
*The dog did go for a walk*  
*The boy be late for school*  
*Alex write a letter*



# Recent one-month usage snapshot

- 120,000 sentences
- 21,000 distinct correct answers
- 5,000 distinct incorrect answers
- 170 error types



# Snapshot error frequencies

Freq	Error type
605	Missing article
151	Subj-V number mismatch
147	Det-N number mismatch
109	Run-on sentence
86	Misplaced adjective
56	Pronoun case
55	Sentence-initial conjunction
43	Past-tense verb form
33	<i>good</i> as adverb
29	Space before comma
27	Missing apostrophe in contraction
26	Misspelled <i>too</i> as <i>to</i>
26	Missing prep for directional <i>go</i>
...	...
2019	Total



# Paragraph composition: Supporting sentence

- Imagine that you ran for class president.
- Write a **supporting sentence** that can come after this lead sentence.
- The day I was elected class president was one of the most exciting days of my life! \_\_\_\_\_

## Modifiers

also  
excited  
exciting  
first  
happiest  
nervous  
nervously  
really  
scariest

## Nouns

class  
classmates  
friends  
poll  
polls  
president  
school  
speech  
speeches  
students  
votes  
winner

## Verbs

chosen  
felt  
vote  
voting  
watched  
win  
won  
feeling  
spoke  
voted  
waited  
went  
winning

Type your answer here



# Paragraph composition: Basic vocabulary

- Imagine that you ran for class president.
- Write a **supporting sentence** that can come
- The day I was elected class president was one of my life! \_\_\_\_\_

## Modifiers

also  
excited  
exciting  
first  
happiest  
nervous  
nervously  
really  
scariest

## Nouns

class  
classmates  
friends  
poll  
polls  
president  
school  
speech  
speeches  
students  
votes  
winner

## Verbs

chosen  
felt  
vote  
voting  
watched  
win  
won

feeling  
spoke  
voted  
waited  
went  
winning

A

B

C

D

day  
did  
didn't  
different  
do  
does  
doesn't  
doing  
done  
don't  
down  
during

Type your answer here



## Sample student paragraph

20120312211040 I went to beach with my family yesterday.  
20120312211101 I went to the beach with my family yesterday.  
20120312211224 At the beach we made sandcastles.  
20120312211339 We went swimming in the ocean.  
20120312211429 We read books at the beach.  
20120312211546 I had a fun time at the beach.





## Another student paragraph

20120322082558 Dinosaurs dinosaurs dinosaurs.  
20120322082628 Pictures pictures pictures books bus.  
20120322082644 Books books books.

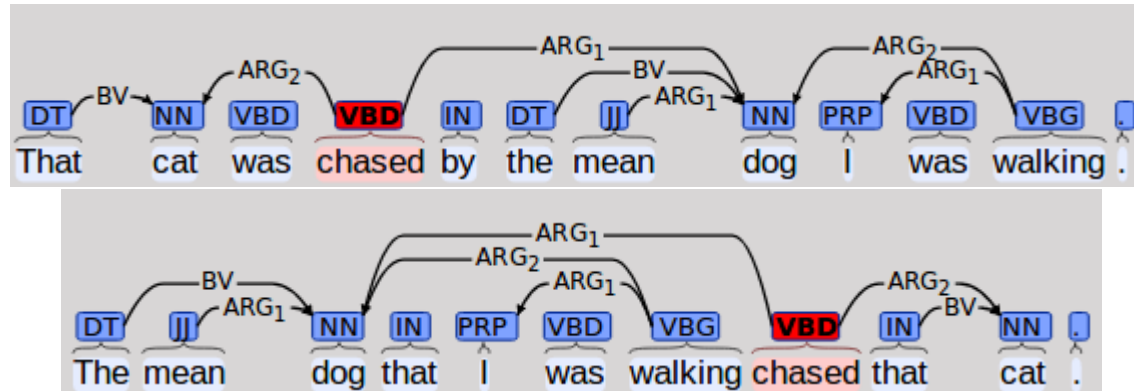


# Semantic evaluation

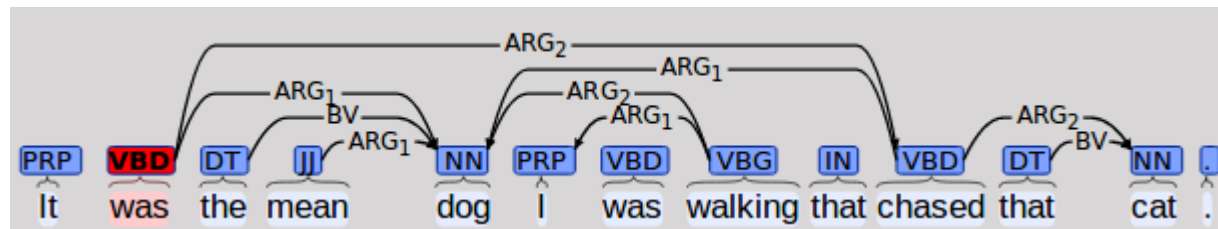
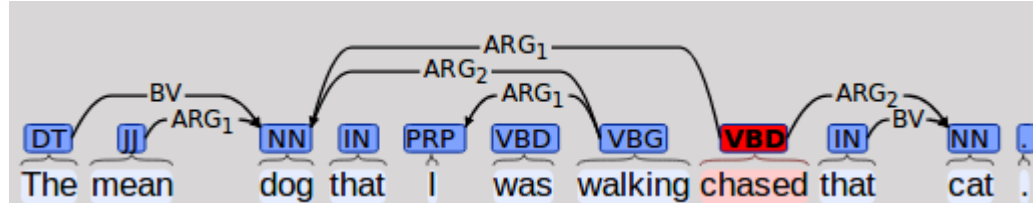
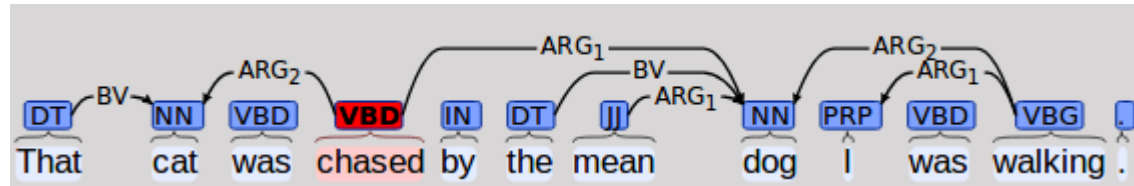
- For single sentence tasks, identify errors in meaning
- Include reference answers provided by exercise authors
- Do graph-based comparison of semantics of student's sentence
- Classify mismatches into small number of error types
  - Wrong subject or object
  - Wrong main verb
  - Missing argument
  - Wrong or missing modifier



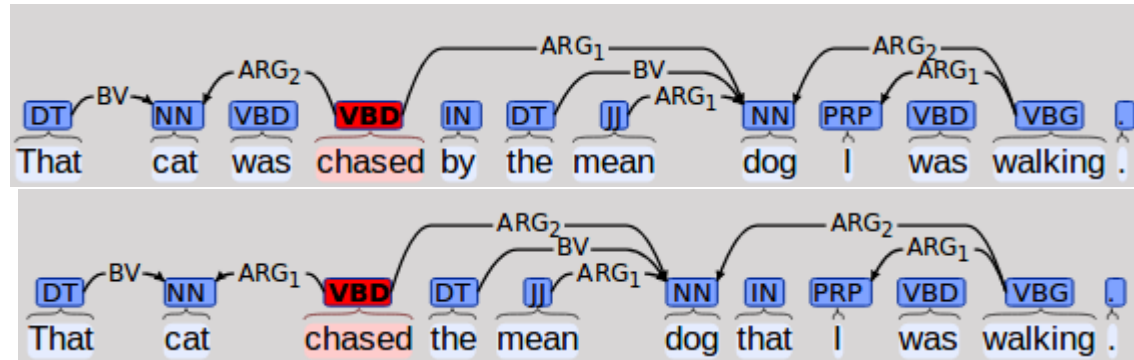
# Semantic comparison: match



# Semantic comparison: match



# Semantic comparison: mismatch



# In development

- Automated paraphrase generation to improve semantic error detection
- Short essays: Error-checking of open-vocabulary compositions  
Grammatical errors and style recommendations
- First-language influence on English error types and frequencies  
Collaboration with Hong Kong Polytechnic for Mandarin speakers
- Generation of corrected student sentences  
Using semantics from incorrect sentence, disabling mal-rules



# Efficacy study

- 5,000 students over two years (2009-2011)
- Memphis public schools (grades 2-6)
- Compared annual state exam results
- Correlated with amount of positive LA&W coursework



# Efficacy study

## Case Study: Shelby County School District\*

