



Learning Science Group

Improving Textbook Accessibility through AI Simplification: Readability Improvements and Meaning Preservation

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Motivation

Students struggle with textbook readability

- Textbook = gold standard, but writing often too complex
- Students cite difficulty, give up reading
- Access and equity concern

"Students who struggle with extracting important information and making meaning from textbook reading do not have the same access to course material as competent textbook readers. Helping all students comprehend textbook reading is an equity issue." (Sheridan-Thomas, 2008, p. 267 [7])

Why Simplification Matters to Students

From student user interviews:

- Many students skip content they don't understand
- Reading challenges disrupt their learning flow
- *"I'd rather not waste my time on something I'm not gonna understand"*
- *"Sometimes the textbook just makes it sound more formal"*

Making Textbooks Easier to Read

A new LLM-powered “Simplify” feature in the Bookshelf ereader

- Students highlight text → receive simplification
- Real-time, student-initiated use
- Designed to reduce lexical/syntactic complexity
- Focuses on simplification, not summarization

Bookshelf Ereader

10.2 Properties of Liquids

The intermolecular forces between molecules in the liquid state vary depending upon their chemical identities and result in corresponding variations in various physical properties. Cohesive forces between like molecules are responsible for a liquid's viscosity (resistance to flow) and surface tension (elasticity of a liquid surface). Adhesive forces between the molecules of a liquid and different molecules composing a surface in contact with the liquid are responsible for phenomena such as surface wetting and capillary rise.

10.3 Phase Transitions

Phase transitions are processes that convert matter between the three phases of matter. Melting, vaporization, and sublimation are endothermic processes, requiring an input of heat to overcome intermolecular attractions. Freezing, condensation, and deposition are all exothermic processes, involving heat as intermolecular attractions are strengthened. The temperatures at which phase transitions occur are determined by the nature of the intermolecular attractions and are, therefore, dependent on the chemical identity of the substance.

10.4 Phase Diagrams

There are six phase transitions between the three phases of matter. Melting, vaporization, and sublimation are endothermic processes, requiring an input of heat to overcome intermolecular attractions. Freezing, condensation, and deposition are all exothermic processes, involving heat as intermolecular attractions are strengthened. The temperatures at which phase transitions occur are determined by the nature of the intermolecular attractions and are, therefore, dependent on the chemical identity of the substance.



Add Note

Copy

Look up in Wikipedia

Create Flashcard

Read Aloud from here

Simplify NEW

Bookshelf Ereader

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Less

Sure! I can simplify this for you:

The forces between molecules in a liquid can change based on what the molecules are made of. These forces affect how the liquid behaves. When molecules stick to each other, they make the liquid thick and hard to pour, which is called viscosity. They also make the surface of the liquid stretchy, which is called

* This content was generated by AI and may contain mistakes. Be sure to check important information.

Research Questions

What this study explores:

- RQ1: Does simplification improve readability?
- RQ2: Is meaning preserved?

Dataset

- Collected Fall 2024 – Spring 2025
- Natural learning contexts
- 54,371 simplification events
- 11,689 students
- 2,082 textbooks
- Top subjects: Social Science, Political Science, Psychology
- Available in our open data repository

Method

How simplifications were generated and evaluated

- GPT-4o, configured for deterministic output
- Prompted to act as a “helpful college professor”

Metrics:

- **Readability:** FKGL, FRE
- **Lexical:** word frequency, word length
- **Syntactic:** tree depth, sentence length
- **Semantic:** cosine similarity, compression ratio

Results Overview

Table 1

Descriptive statistics for readability, lexical, syntactic, and semantic fidelity metrics for simplification events.

| Category | Metric | Mean | SD | Q ₁ | Median | Q ₃ |
|-------------|---------------------------|--------|-------|----------------|--------|----------------|
| Readability | Δ FKGL | -7.37 | 4.61 | -9.20 | -6.53 | -4.51 |
| | Δ FRE | 31.34 | 16.95 | 20.18 | 29.33 | 40.07 |
| Lexical | Δ log p | 1.02 | 0.52 | 0.66 | 0.98 | 1.33 |
| | Δ chars / word | -0.41 | 0.37 | -0.62 | -0.38 | -0.17 |
| Syntactic | Δ dependency depth | -0.98 | 0.81 | -1.33 | -0.87 | -0.48 |
| | Δ words / sentence | -14.62 | 13.28 | -18.65 | -11.45 | -6.62 |
| Semantic | Cosine similarity | .85 | .08 | .81 | .87 | .91 |
| | Compression ratio | 0.80 | 0.22 | 0.66 | 0.79 | 0.92 |

Readability improved, meaning preserved

Readability Results

Readability improved dramatically

- FKGL: -7.4 grade levels
- FRE: +31 points

Average simplified text ~9th grade level

Lexical and Syntactic Results

Texts became simpler in structure and vocabulary

Lexical:

- More common words ($\Delta \log p = +1.02$, $\sim 2.8x$)
- Shorter words (-0.41 characters/word)

Syntactic:

- Shallower dependency trees (-0.98 levels)
- Shorter sentences (-14.6 words)

Semantic Fidelity Results

High semantic retention despite simplification

- Mean cosine similarity (`all-mpnet-base-v2`) = .85
- 94.5% of simplifications above acceptability threshold
- Mean compression ratio = 0.80

Example (Social Science)

Cosine = .55, FKGL 19.0 → 7.2

Original

Insofar as corrections remains at the heart of our social policy—rather than as a supplemental or marginal support as it was throughout most of United States history—it is the Iron State stealing from the future of the Golden State.

Simplified

When we focus too much on prisons as a main part of our social policy, it takes away from other important areas. In the past, prisons were just a small part of our approach. Now, they take up a lot of attention and resources. This focus on prisons is like taking away from our future growth and success.

Example (Psychology)

Cosine = .54, compression ratio = 0.36

Original

Reaction chains are similar to FAPs, but with one major difference—each set of responses in a reaction chain requires an appropriate stimulus to set it off. Recall that once a fixed-action pattern (FAP) begins, the animal usually continues the sequence even when the stimuli that set off the behavior are removed. In the previous squirrel and nuts example, the animal continues to dig a hole and bury the non-existent nut, even if the nut is removed. In contrast, a reaction chain requires the presence of a specific stimulus to activate each link in the sequence of behavior. An organism's performance produces stimuli that set off the next series of responses in the chain; these behaviors in turn produce the stimuli followed by another set of responses. Presenting a stimulus that ordinarily occurs in the middle part of the sequence activates the chain at that point rather than at the beginning. Also, unlike FAPs, if the stimuli that activate behavior are removed, the sequence is disrupted. The courtship ritual of the male and female stickleback fish (*Gasterosteus aculeatus*) is a reaction chain (Figure 3.2). Reaction chains often show behavioral flexibility similar to MAPs, but here we describe an idealized behavioral sequence. During the mating season, the reaction chain is initiated when a male stickleback sees a female and begins a zigzag dance, displaying his red underbelly. For a receptive female with eggs, the male's display functions as a stimulus that causes the female to arch her back and reveal her swollen abdomen. This initiates swimming by the male to a previously constructed nest. The female follows and enters the nest with her tail protruding, causing the male to nibble at the base of her tail and initiate the egg-laying sequence. Once the female has deposited her eggs, the male ousts her from the nest, enters the nest, and fertilizes the eggs, thereby completing the reaction chain.

Example (Psychology)

Cosine = .54, compression ratio = 0.36

Simplified

Reaction chains and fixed-action patterns (FAPs) are alike, but they have a key difference. In a reaction chain, each step needs a specific trigger to start. Once a FAP starts, the animal keeps going even if the trigger is gone. For example, a squirrel will keep burying a nut even if the nut is taken away. But in a reaction chain, each step needs its own trigger to happen. The animal's actions create new triggers for the next steps. If you give a trigger that usually happens in the middle, the chain starts there instead of at the beginning. Unlike FAPs, if you take away the triggers in a reaction chain, the sequence stops.

Limitations and Next Steps

This was linguistic analysis only, not comprehension or learning outcomes

Future work:

- Student feedback (e.g., 👍 / 👎)
- Studies of educational impact
- Adaptive supports (inline glosses, elaboration tuning)

Key Takeaways

- Simplification improved readability dramatically
- Meaning preserved in ~95% of cases
- Textbook writing often includes unnecessary complexity
- Offers better access for students who struggle with dense academic language
- Promising direction for improving equity in learning

Thank You!

Contact: benny.johnson@vitalsource.com

Acknowledgments

- Publishers who partnered on generative AI research
- Reviewers for their constructive feedback



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