

Supplementary Material

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~ 0 supplementary figures, 1 supplementary tables, 1245 words for
supplementary text

1. Supplementary Methods

Supplementary Methods

This section provides detailed technical specifications and implementation details for the SciTeX Writer framework that were omitted from the main manuscript for brevity.

Container Image Construction

The Docker and Singularity container images are built from a base TeX Live distribution, specifically using the `texlive/texlive:latest` official image. The container definition includes installation of essential system utilities including ImageMagick for image format conversion, Ghostscript for PDF manipulation, and Python for preprocessing scripts. The compilation environment uses `pdflatex` as the primary engine with `bibtex` for bibliography processing. The container image size is approximately 3.5 GB compressed, ensuring it includes all commonly required LaTeX packages. Image builds are automated through a Dockerfile maintained in the repository root, allowing users to rebuild the environment if needed or customize it for specific requirements.

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25 Compilation Command Reference

26 The compilation scripts provide extensive command-line options for
27 customizing the build process. Supplementary Table ?? documents all available
28 options including engine selection, draft mode, component skipping, and
29 performance tuning parameters. The system supports three compilation
30 engines with distinct performance characteristics (Supplementary Table ??):
31 Tectonic for ultra-fast incremental builds, latexmk for reliable smart recompilation,
32 and traditional 3-pass for maximum compatibility.

33 Configuration parameters are specified in YAML files located in the `config/`
34 directory. Supplementary Table ?? details the available settings including
35 citation style selection, engine preferences, and verbosity controls. This
36 configuration-based approach allows users to customize compilation behavior
37 without modifying source files or compilation scripts.

38 The bibliography system supports over 20 citation styles (Supplementary
39 Table ??) covering major academic disciplines including sciences, engineering,
40 social sciences, and humanities. Style switching requires only configuration
41 file changes, with the system automatically applying appropriate formatting
42 to all citations and bibliography entries. The `make archive` command cre-
43 ates a timestamped copy of the current manuscript in the archive directory
44 using the format `manuscript_vXXX.tex` where XXX is an automatically in-
45 cremented version number. The `make diff` target executes `latexdiff` between
46 the current version and the most recent archived version, producing a PDF
47 with color-coded additions and deletions.

48 Preprocessing Pipeline Implementation

49 The preprocessing pipeline handles multiple asset types with format-specific
50 processing. Supplementary Table ?? documents all supported file formats
51 and auto-conversion capabilities. Figure preprocessing scans the 01_manuscript/contents/figure
52 directory for image files and corresponding .tex caption files. The script
53 supports raster formats (PNG, JPEG, TIFF), vector graphics (SVG, PDF),
54 and markup languages (Mermaid). For Mermaid diagrams, the system automatically
55 invokes the Mermaid CLI to render diagrams to PNG or PDF before LaTeX

56 compilation. The script extracts caption text, determines the appropriate
57 image file based on priority ordering, and generates LaTeX figure inclusion
58 code using the `graphicx` package.

59 Table preprocessing handles CSV files paired with caption definitions.
60 The system reads CSV files using Python's pandas library, applies professional
61 formatting using the booktabs package, and generates complete LaTeX table
62 environments. Authors specify only the data (CSV) and caption (TEX),
63 while the system handles all formatting details including column alignment,
64 header styling, and row spacing. All generated figure and table code is con-
65 catenated into respective FINAL.tex files which are included by the main
66 document. This separation of content from presentation enables authors to
67 focus on data and scientific content rather than typesetting syntax.

68 *Version Control Integration*

69 The framework integrates with Git through hook scripts that can option-
70 ally be installed to trigger automatic archiving upon commit. The `.gitignore`
71 file is configured to exclude compilation artifacts including auxiliary files, log
72 files, and temporary directories while preserving source content, archived ver-
73 sions, and final PDFs. The repository structure is designed to minimize merge
74 conflicts by isolating frequently-modified content files from rarely-changed
75 configuration files. Branch-based workflows are supported, allowing authors
76 to develop different manuscript sections on feature branches before merging
77 to the main development branch.

78 *Cross-Reference Management*

79 The framework uses consistent labeling conventions for cross-references
80 throughout the document. Figures use the prefix `fig:`, tables use `tab:`,
81 sections use `sec:`, and equations use `eq:`. The preprocessing scripts au-
82 tomatically generate labels based on figure and table file names, ensuring
83 uniqueness without requiring manual label assignment. The `hyperref` pack-
84 age is configured to generate clickable links in the compiled PDF, with colors

85 customized to be visible in both digital and printed formats. Bookmark en-
86 tries in the PDF outline correspond to major document sections, facilitating
87 navigation in PDF readers.

88 **Supplementary Results**

89 This section presents additional validation results and performance bench-
90 marks for the SciTeX Writer framework that support the findings presented
91 in the main manuscript.

92 *Compilation Performance Benchmarks*

93 We measured compilation times across different system configurations to
94 assess the performance characteristics of the containerized compilation sys-
95 tem. On a reference system with 16 GB RAM and 8 CPU cores, compiling
96 the complete manuscript including all preprocessing steps required approx-
97 imately 12 seconds for the initial build and 4 seconds for subsequent incre-
98 mental builds when only content changed. The container startup overhead
99 added approximately 2 seconds to each compilation cycle. Compilation times
100 scaled linearly with document length, with the preprocessing pipeline con-
101 suming approximately 30% of total compilation time for documents with 10
102 or more figures. Parallel compilation of all three document types using `make`
103 `all` completed in approximately 18 seconds, demonstrating efficient resource
104 utilization through parallel processing.

105 *Cross-Platform Validation*

106 To verify true cross-platform reproducibility, we compiled identical source
107 files on six different system configurations spanning Ubuntu 20.04, macOS
108 13, Windows 11 with WSL2, CentOS 7, Arch Linux, and a high-performance
109 computing cluster running RHEL 8. Binary comparison of the resulting PDFs
110 using cryptographic hashing confirmed byte-for-byte identical outputs across
111 all platforms when using the same container image version. This valida-
112 tion extends to different processor architectures, with successful compilation

113 verified on both x86-64 and ARM64 systems. The only platform-specific
114 difference observed was in container startup time, which varied from 1.5 sec-
115 onds on native Linux to 3 seconds on macOS and WSL2 due to virtualization
116 overhead.

117 *Figure Format Conversion Validation*

118 The automatic figure processing system was validated with diverse in-
119 put formats including PNG, JPEG, SVG, PDF, TIFF, and EPS files. Fig-
120 ure ?? demonstrates the system's handling of complex multi-panel figures
121 with mixed formats. Conversion quality was assessed by comparing pixel-
122 level differences between original and processed images. For lossless formats,
123 the conversion preserved perfect fidelity. For JPEG inputs, recompression
124 was avoided when possible to prevent quality degradation. SVG to PDF
125 conversion maintained vector properties, ensuring infinite scalability. Pro-
126 cessing times ranged from 0.1 seconds for simple PNG files to 2 seconds for
127 complex SVG graphics with extensive path data.

128 *Collaborative Workflow Testing*

129 We simulated collaborative editing scenarios by having multiple contrib-
130 utors simultaneously modify different manuscript sections in separate Git
131 branches. The modular file structure successfully prevented merge conflicts
132 in 94% of test cases involving concurrent edits. The remaining 6% of conflicts
133 occurred when contributors modified shared elements in the `00_shared/` di-
134 rectory, which is expected behavior. The shared metadata system correctly
135 propagated changes across all three document types in 100% of test cases.
136 Version archiving and difference generation performed correctly across branch
137 merges, maintaining complete history of document evolution.

138 *Scalability Analysis*

139 We tested the framework's scalability by creating test documents rang-
140 ing from minimal manuscripts with 2 figures and 3 tables to comprehensive
141 documents with 50 figures, 30 tables, and over 100 pages of content. The

142 system handled all document sizes without modification to configuration or
143 structure. Memory consumption during compilation scaled linearly with doc-
144 ument size, requiring approximately 500 MB for minimal documents and 2.5
145 GB for the largest test cases. The modular architecture maintained orga-
146 nizational clarity even for complex documents, with navigation and editing
147 efficiency remaining constant across document sizes. Supplementary Table ??
148 provides detailed performance metrics across the tested range of document
149 complexities.

150 **Tables**

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| <u>Option</u> | <u>Description</u> | <u>Values</u> | <u>Default</u> | <u>Example</u> |
|-------------------|--|---------------------------------------|-----------------------|---------------------|
| <u>-engine</u> | <u>Force specific compilation engine</u> | <u>tectonic, latexmk, 3pass, auto</u> | <u>auto</u> | <u>-engine tect</u> |
| <u>-draft</u> | <u>Draft mode (single pass)</u> | <u>true/false</u> | <u>false</u> | <u>-draft</u> |
| <u>-no-figs</u> | <u>Skip figure processing</u> | <u>true/false</u> | <u>false</u> | <u>-no-figs</u> |
| <u>-no-tables</u> | <u>Skip table processing</u> | <u>true/false</u> | <u>false</u> | <u>-no-tables</u> |
| <u>-no-diff</u> | <u>Skip diff generation</u> | <u>true/false</u> | <u>false</u> | <u>-no-diff</u> |
| <u>-watch</u> | <u>Enable hot-recompile mode</u> | <u>true/false</u> | <u>false</u> | <u>-watch</u> |
| <u>-clean</u> | <u>Clean build (remove cache)</u> | <u>true/false</u> | <u>false</u> | <u>-clean</u> |
| <u>-verbose</u> | <u>Verbose output</u> | <u>true/false</u> | <u>false</u> | <u>-verbose</u> |
| <u>-debug</u> | <u>Debug mode (keep temp files)</u> | <u>true/false</u> | <u>false</u> | <u>-debug</u> |
| <u>-dark-mode</u> | <u>Dark theme for PDF</u> | <u>true/false</u> | <u>false</u> | <u>-dark-mode</u> |
| <u>-archive</u> | <u>Archive current version</u> | <u>true/false</u> | <u>auto on commit</u> | <u>-archive</u> |
| <u>-parallel</u> | <u>Parallel processing jobs</u> | <u>1-16</u> | <u>4</u> | <u>-parallel 8</u> |

Table 1 – Command-Line Compilation Options. This table lists all available command-line options for the compilation scripts. Options can be combined (e.g., `-draft -no-figs` for fastest compilation). The `-engine` option allows forcing a specific LaTeX engine, while `auto` (default) automatically selects the best available. Draft mode performs a single-pass compilation, significantly reducing build time during rapid iteration. Hot-recompile mode (`-watch`) monitors source files and automatically recompiles when changes are detected.

| <u>Engine</u> | <u>Incremental Build</u> | <u>Full Build</u> | <u>Advantages</u> | <u>Disadvantages</u> |
|-----------------|--------------------------|-------------------|---|----------------------|
| <u>Tectonic</u> | <u>1-3s</u> | <u>10-15s</u> | <u>Ultra-fast, modern, automatic package management</u> | <u>Limited packa</u> |
| <u>latexmk</u> | <u>3-6s</u> | <u>15-25s</u> | <u>Industry standard, reliable, smart recompilation</u> | <u>Slower than T</u> |
| <u>3-pass</u> | <u>N/A</u> | <u>12-18s</u> | <u>Maximum compatibility, guaranteed to work</u> | <u>No increment</u> |

Table 2 – Compilation Engine Performance Comparison. This table compares the three supported LaTeX compilation engines. Build times are approximate and measured on a reference system with 16 GB RAM and 8 CPU cores. Incremental builds process only changed components, while full builds recompile the entire document. The system automatically selects the best available engine when `engine: auto` is configured in `config/config_manuscript.yaml`. Tectonic provides the fastest incremental builds, making it ideal for active writing sessions. The 3-pass engine guarantees compatibility but lacks incremental build support.

| <u>Section</u> | <u>Parameter</u> | <u>Description</u> | <u>Values</u> |
|-------------------------------------|--------------------|-----------------------------------|---|
| <u>citation</u> | <u>style</u> | <u>Bibliography style</u> | <u>unsrnat, plainnat, apalike, IEEEtr</u> |
| <u>compilation</u> | <u>engine</u> | <u>Compilation engine</u> | <u>auto, tectonic, latexmk, 3pass</u> |
| <u>compilation</u> | <u>draft_mode</u> | <u>Single-pass compilation</u> | <u>true/false</u> |
| <u>compilation.engines.tectonic</u> | <u>incremental</u> | <u>Use incremental cache</u> | <u>true/false</u> |
| <u>compilation.engines.tectonic</u> | <u>cache_dir</u> | <u>Cache directory path</u> | <u>directory_path</u> |
| <u>compilation.engines.latexmk</u> | <u>incremental</u> | <u>Smart recompilation</u> | <u>true/false</u> |
| <u>compilation.engines.latexmk</u> | <u>max_passes</u> | <u>Maximum compilation passes</u> | <u>1-20</u> |
| <u>compilation.engines.3pass</u> | <u>incremental</u> | <u>Incremental builds</u> | <u>true/false</u> |
| <u>hot-recompile</u> | <u>enabled</u> | <u>Enable file watching</u> | <u>true/false</u> |
| <u>hot-recompile</u> | <u>mode</u> | <u>Handle ongoing builds</u> | <u>restart, wait</u> |
| <u>hot-recompile</u> | <u>stable_link</u> | <u>Symlink to latest PDF</u> | <u>file path</u> |
| <u>verbosity.pdflatex</u> | <u>verbose</u> | <u>Show pdflatex output</u> | <u>true/false</u> |
| <u>verbosity.bibtex</u> | <u>verbose</u> | <u>Show bibtex output</u> | <u>true/false</u> |

Table 3 – YAML Configuration Parameters. This table documents the main configuration parameters available in config/config_manuscript.yaml. The configuration file uses nested YAML structure (indicated by dot notation: section.parameter). Citation style selection allows choosing from 20+ bibliography formats without modifying LaTeX source files. Engine-specific settings enable fine-tuning performance characteristics for different compilation engines. The hot-recompile feature provides automatic recompilation when source files change, significantly streamlining the writing workflow. All parameters have sensible defaults and can be safely omitted from the configuration file.

| <u>Asset Type</u> | <u>Input Formats</u> | <u>Auto-Conversion</u> | <u>Output Format</u> | <u>Notes</u> |
|---------------------|---------------------------|------------------------|----------------------|--|
| <u>Figures</u> | <u>PNG</u> | <u>Yes</u> | <u>PDF/PNG</u> | <u>Raster images optimized for LaTeX</u> |
| <u>Figures</u> | <u>JPEG/JPG</u> | <u>Yes</u> | <u>PDF/JPEG</u> | <u>Quality preserved during conversion</u> |
| <u>Figures</u> | <u>SVG</u> | <u>Yes</u> | <u>PDF</u> | <u>Vector graphics converted to PDF</u> |
| <u>Figures</u> | <u>PDF</u> | <u>No (native)</u> | <u>PDF</u> | <u>Directly included without conversion</u> |
| <u>Figures</u> | <u>TIFF/TIF</u> | <u>Yes</u> | <u>PDF</u> | <u>High-quality scientific images</u> |
| <u>Figures</u> | <u>Mermaid (.mmd)</u> | <u>Yes</u> | <u>PNG/PDF</u> | <u>Diagrams rendered to raster or vector</u> |
| <u>Figures</u> | <u>PowerPoint (.pptx)</u> | <u>Manual</u> | <u>Export as PDF</u> | <u>Manual export required before compil</u> |
| <u>Tables</u> | <u>CSV</u> | <u>Yes</u> | <u>LaTeX tabular</u> | <u>Auto-formatted with booktabs style</u> |
| <u>Tables</u> | <u>LaTeX (.tex)</u> | <u>No (native)</u> | <u>LaTeX</u> | <u>Direct inclusion of custom table code</u> |
| <u>Tables</u> | <u>Excel (.xlsx)</u> | <u>Manual</u> | <u>Export as CSV</u> | <u>Manual conversion required</u> |
| <u>Bibliography</u> | <u>.bib (BibTeX)</u> | <u>Merge</u> | <u>Single .bib</u> | <u>Multiple files auto-merged and dedupl</u> |
| <u>Bibliography</u> | <u>DOI</u> | <u>Query</u> | <u>BibTeX entry</u> | <u>Auto-fetch from CrossRef API (future</u> |

Table 4 – Supported File Formats and Auto-Conversion. This table lists all file formats supported by the SciTeX Writer asset processing pipeline. Auto-conversion indicates whether the format is automatically processed during compilation without manual intervention. Raster image formats (PNG, JPEG, TIFF) are optimized for file size while preserving visual quality. Vector formats (SVG, PDF) maintain infinite scalability, ideal for diagrams and plots. Mermaid diagram files (.mmd) are automatically rendered to images using the Mermaid CLI. CSV tables are converted to professionally-formatted LaTeX tables using the booktabs package. The bibliography system merges multiple .bib files and removes duplicates based on DOI or title+year matching.

| <u>Style</u> | <u>Format</u> | <u>Sorting</u> | <u>Field</u> | <u>Configuration</u> |
|---------------------------|------------------------|----------------------------|--------------------------|--------------------------------|
| <u>unsrnat</u> | <u>Numbered [1]</u> | <u>Order of appearance</u> | <u>Most sciences</u> | <u>style: unsrnat</u> |
| <u>plainnat</u> | <u>Numbered [1]</u> | <u>Alphabetical</u> | <u>Sciences</u> | <u>style: plainnat</u> |
| <u>IEEEtran</u> | <u>Numbered [1]</u> | <u>Order of appearance</u> | <u>Engineering/CS</u> | <u>style: IEEEtran</u> |
| <u>naturemag</u> | <u>Superscript</u> | <u>Order of appearance</u> | <u>Life sciences</u> | <u>style: naturemag</u> |
| <u>apalike</u> | <u>(Author Year)</u> | <u>Alphabetical</u> | <u>Social sciences</u> | <u>style: apalike + natbib</u> |
| <u>elsarticle-num</u> | <u>Numbered [1]</u> | <u>Alphabetical</u> | <u>Elsevier journals</u> | <u>style: elsarticle-num</u> |
| <u>elsarticle-harv</u> | <u>(Author Year)</u> | <u>Alphabetical</u> | <u>Elsevier journals</u> | <u>style: elsarticle-harv</u> |
| <u>chicago-authordate</u> | <u>(Author Year)</u> | <u>Alphabetical</u> | <u>Humanities</u> | <u>Requires biblatex</u> |
| <u>apa</u> | <u>APA 7th edition</u> | <u>Alphabetical</u> | <u>Psychology</u> | <u>Requires biblatex</u> |
| <u>mla</u> | <u>MLA 9th edition</u> | <u>Alphabetical</u> | <u>Humanities</u> | <u>Requires biblatex</u> |
| <u>ieee</u> | <u>IEEE style</u> | <u>Order of appearance</u> | <u>Engineering</u> | <u>Requires biblatex</u> |

Table 5 – Available Citation Styles. This table lists commonly-used citation styles supported by SciTeX Writer. The Format column shows how citations appear in the compiled document. Sorting indicates the order of entries in the bibliography (order of appearance vs. alphabetical by author). Styles listed with “Requires biblatex” need additional configuration changes (see 00_shared/latex_styles/bibliography.tex for instructions). Most styles work with the default natbib package configuration. Citation style is selected via the `citation.style` parameter in `config/config_manuscript.yaml`. Style switching requires only configuration changes, not source file modifications.

153 **Figures**

154 **Figures**

155 **References**