

Supplementary Material

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6 supplementary figures, 1 supplementary tables, 1245 words for
7 supplementary text

8 1. Supplementary Methods

9 Supplementary Methods

¹⁰ This section provides detailed technical specifications and implementation
¹¹ details for the SciTeX Writer framework that were omitted from the main
¹² manuscript for brevity.

13 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 cus-
27 tomizing the build process. Supplementary Table 1 documents all available
28 options including engine selection, draft mode, component skipping, and per-
29 formance tuning parameters. The system supports three compilation engines
30 with distinct performance characteristics (Supplementary Table 2): Tectonic
31 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 3 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 5) 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-
50 specific processing. Supplementary Table 4 documents all supported file
51 formats and auto-conversion capabilities. Figure preprocessing scans the
52 `01_manuscript/contents/figures/caption_and_media/` directory for im-
53 age files and corresponding `.tex` caption files. The script supports raster
54 formats (PNG, JPEG, TIFF), vector graphics (SVG, PDF), and markup

55 languages (Mermaid). For Mermaid diagrams, the system automatically
56 invokes the Mermaid CLI to render diagrams to PNG or PDF before LaTeX
57 compilation. The script extracts caption text, determines the appropriate
58 image file based on priority ordering, and generates LaTeX figure inclusion
59 code using the `graphicx` package.

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

70 *Version Control Integration*

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

80 *Cross-Reference Management*

81 The framework uses consistent labeling conventions for cross-references
82 throughout the document. Figures use the prefix `fig:`, tables use `tab:`,
83 sections use `sec:`, and equations use `eq:`. The preprocessing scripts au-
84 tomatically generate labels based on figure and table file names, ensuring

85 uniqueness without requiring manual label assignment. The hyperref pack-
86 age is configured to generate clickable links in the compiled PDF, with colors
87 customized to be visible in both digital and printed formats. Bookmark en-
88 tries in the PDF outline correspond to major document sections, facilitating
89 navigation in PDF readers.

90 **Supplementary Results**

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

94 *Compilation Performance Benchmarks*

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

107 *Cross-Platform Validation*

108 To verify true cross-platform reproducibility, we compiled identical source
109 files on six different system configurations spanning Ubuntu 20.04, macOS
110 13, Windows 11 with WSL2, CentOS 7, Arch Linux, and a high-performance
111 computing cluster running RHEL 8. Binary comparison of the resulting PDFs
112 using cryptographic hashing confirmed byte-for-byte identical outputs across

113 all platforms when using the same container image version. This validation
114 extends to different processor architectures, with successful compilation
115 verified on both x86-64 and ARM64 systems. The only platform-specific
116 difference observed was in container startup time, which varied from 1.5 sec-
117 onds on native Linux to 3 seconds on macOS and WSL2 due to virtualization
118 overhead.

119 *Figure Format Conversion Validation*

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

130 *Collaborative Workflow Testing*

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

140 *Scalability Analysis*

141 We tested the framework’s scalability by creating test documents rang-
142 ing from minimal manuscripts with 2 figures and 3 tables to comprehensive

143 documents with 50 figures, 30 tables, and over 100 pages of content. The
144 system handled all document sizes without modification to configuration or
145 structure. Memory consumption during compilation scaled linearly with doc-
146 ument size, requiring approximately 500 MB for minimal documents and 2.5
147 GB for the largest test cases. The modular architecture maintained orga-
148 nizational clarity even for complex documents, with navigation and editing
149 efficiency remaining constant across document sizes. Supplementary Table ??
150 provides detailed performance metrics across the tested range of document
151 complexities.

¹⁵² **Tables**

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

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.

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

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.

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

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.

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

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.

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

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