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Visual Literacy in 3D Printing Slicer Interfaces: A Design-Led Study

[1] Sakthi Sree B
[1] ThinkMetal Pvt. Ltd., Chennai, Tamil Nadu, India
Corresponding Author Email: [1] sakthi2ksree@gmail.com

Abstract— ***3D printing has become an integral tool within contemporary design practice, enabling designers, makers, and students to translate digital concepts into physical artifacts. Slicer software interfaces play a critical role in this process by mediating between digital models and fabrication through visual representations of layers, toolpaths, material behavior, and print parameters. As slicer workflows grow more complex, users are increasingly required to interpret dense visual information in order to make timely and accurate fabrication decisions. Many users face persistent challenges in reading and understanding slicer visualizations, particularly when navigating layer previews, infill structures, support systems, and parameter adjustments. These challenges often slow down workflow, increase trial-and-error printing, and contribute to material waste. The issue is not solely technical, but visual: current interfaces frequently rely on abstract or poorly structured visual cues that exceed users' levels of visual literacy, limiting efficient interpretation of fabrication data. This study adopts a design-led approach to examine how slicer interfaces communicate fabrication information and where breakdowns in visual comprehension occur. Through qualitative analysis of widely used open-source slicer software and UX-focused evaluation of key visual elements, the research identifies recurring issues such as weak visual hierarchy, insufficient contextual feedback, and unclear relationships between settings and their physical outcomes. The paper proposes integrating adaptive, AI-driven systems to improve visual communication, guide user attention, and accelerate decision-making within slicer workflows. By enhancing visual interpretation rather than replacing user agency, slicer software is reframed as a visual communication system within UI/UX design, digital fabrication, and emerging computational practices.***

Keywords— ***Additive manufacturing, 3D printing slicer interfaces, Artificial intelligence, Visual literacy, Human–AI interaction, User experience design.***

I. BACKGROUND

Additive manufacturing, commonly referred to as 3D printing, has shifted from a specialized industrial process to an accessible tool across design education, prototyping, and small-scale production. Designers increasingly rely on digital fabrication tools not only for output but also as exploratory and iterative design media. Within this ecosystem, slicer software occupies a critical intermediary role, translating three-dimensional digital models into machine-readable instructions. This translation is not purely computational; it is communicated to users through visual previews, colour codes, diagrams, and layered representations.

Historically, slicer interfaces were relatively minimal, requiring users to possess strong technical knowledge to interpret numerical parameters and geometric abstractions. Contemporary slicers, however, emphasize automation, optimization, and accessibility. Features such as automatic support generation, infill optimization, and print-time estimation rely heavily on visual feedback. As a result, slicer interfaces now function as complex visual information systems rather than simple configuration tools.

Despite these advances, user reports and practitioner experiences indicate persistent misunderstandings of slicer feedback. Users often misinterpret layer previews, fail to notice structural weaknesses, or rely uncritically on automated recommendations. This highlights the importance of visual literacy - the ability to read, interpret, and critically evaluate visual information—within digital fabrication contexts.

II. MOTIVATION AND OBJECTIVE

The motivation for this study emerges from observed gaps between interface sophistication and user comprehension. While automation reduces the need for manual parameter tuning, it simultaneously increases reliance on visual indicators to explain system decisions. When these indicators lack clarity or contextual grounding, users may disengage or lose confidence in the system.

The primary objective of this research is to examine how visual design choices in slicer interfaces influence user understanding and decision-making. Specifically, the study aims to:

A. Identify recurring visual communication breakdowns in contemporary slicer interfaces.
B. Examine how hierarchy, abstraction, and visual metaphor influence interpretability of fabrication data.
C. Explore opportunities for adaptive and explainable AI to support user comprehension.
D. Develop a design-oriented framework for enhancing visual literacy in digital fabrication workflows.

III. RESEARCH METHODOLOGY

This research adopts a design-led qualitative methodology. Rather than evaluating slicer software solely on technical performance, the study approaches these tools as visual communication artifacts. The analysis focuses on widely used open-source slicer applications to ensure relevance and accessibility.

Methods include:

A. Case Selection an`d Scope: Interface mapping to document key visual elements such as layer previews, color encodings, and alert systems.
B. Interface Analysis Framework: Comparative visual analysis to identify patterns of abstraction and hierarchy.
C. Analytical Method: UX-oriented heuristic evaluation focusing on clarity, consistency, and feedback.

The evaluation criteria were informed by established principles in visual communication and human–computer interaction literature.

IV. STATEMENT OF CONTRIBUTION

This paper makes three contributions:

A. It reframes slicer interfaces as visual literacy challenges, positioning digital fabrication tools as visual communication systems rather than purely technical utilities.
B. It identifies recurring visualization breakdowns across contemporary slicer interfaces, revealing systematic mismatches between computational representation and human interpretation.
C. It introduces an AI-supported visual guidance framework that demonstrates how adaptive visualization can support comprehension while preserving human agency in fabrication workflows.

V. RESULTS

Across examined slicer interfaces, recurring visualization patterns revealed systematic challenges in how fabrication information is communicated. Rather than isolated usability flaws, these issues reflect broader mismatches between computational representation and human visual interpretation.

A. Excessive Abstraction:

Color-coded previews often lack clear legends or explanations, assuming prior technical knowledge.

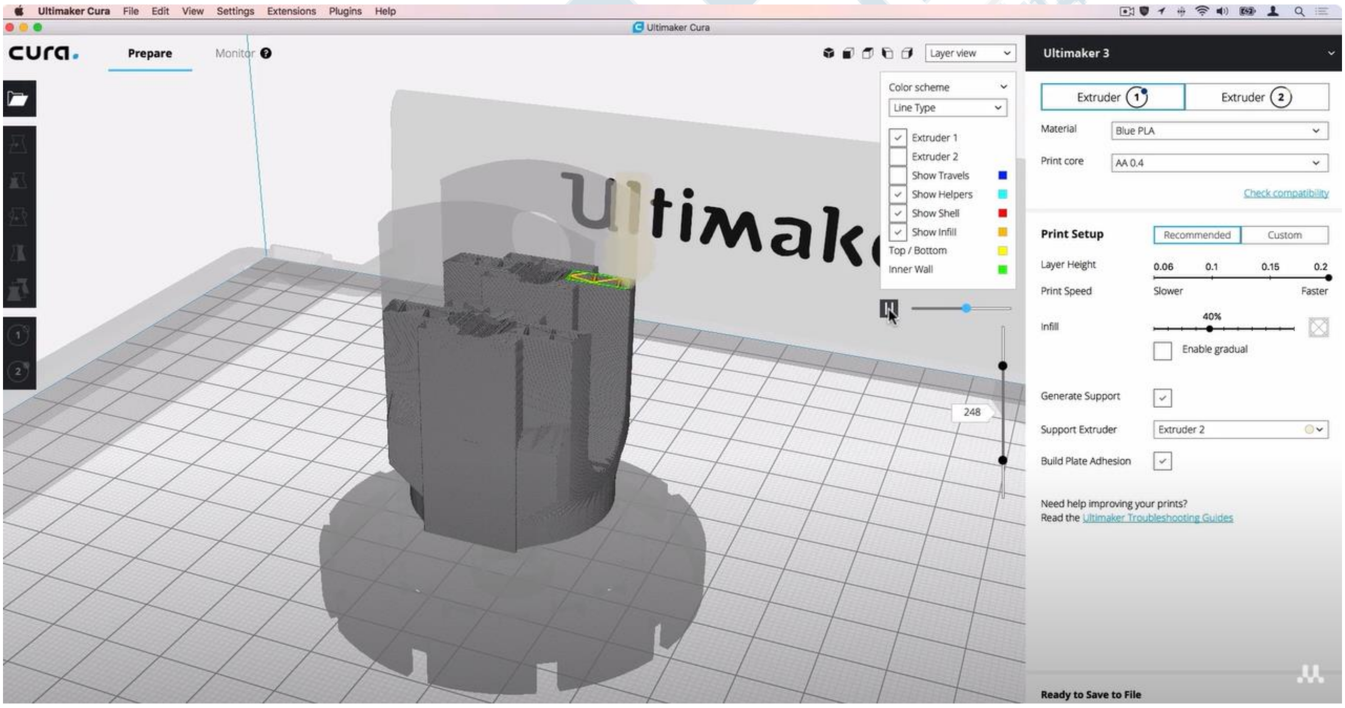

Figure 1. Layer preview interface in Ultimaker Cura displaying color-coded toolpaths, infill structures, and shell layers after slicing

The interface presents dense visual encodings that require users to interpret structural and fabrication implications from abstract representations.

B. Weak Visual Hierarchy:

Critical structural or failure-related information competes visually with secondary data, reducing salience.

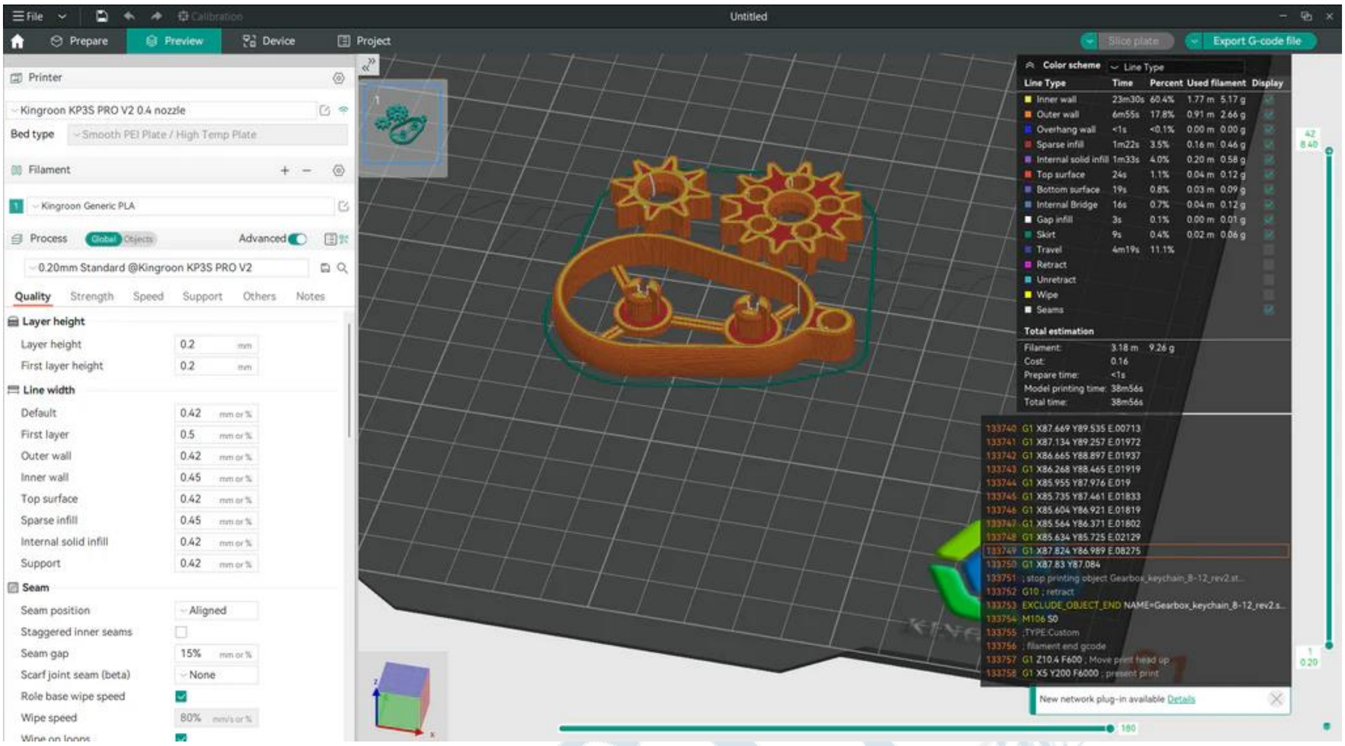

Figure 2. G-code preview interface displaying color-coded toolpaths and filament distribution statistics after slicing

The interface simultaneously presents geometric, parameter, and quantitative data, requiring users to interpret fabrication implications from abstract visual encodings.

C. Limited Contextual Cues:

Automated decisions are rarely explained visually, leading users to accept or reject recommendations without understanding their basis.

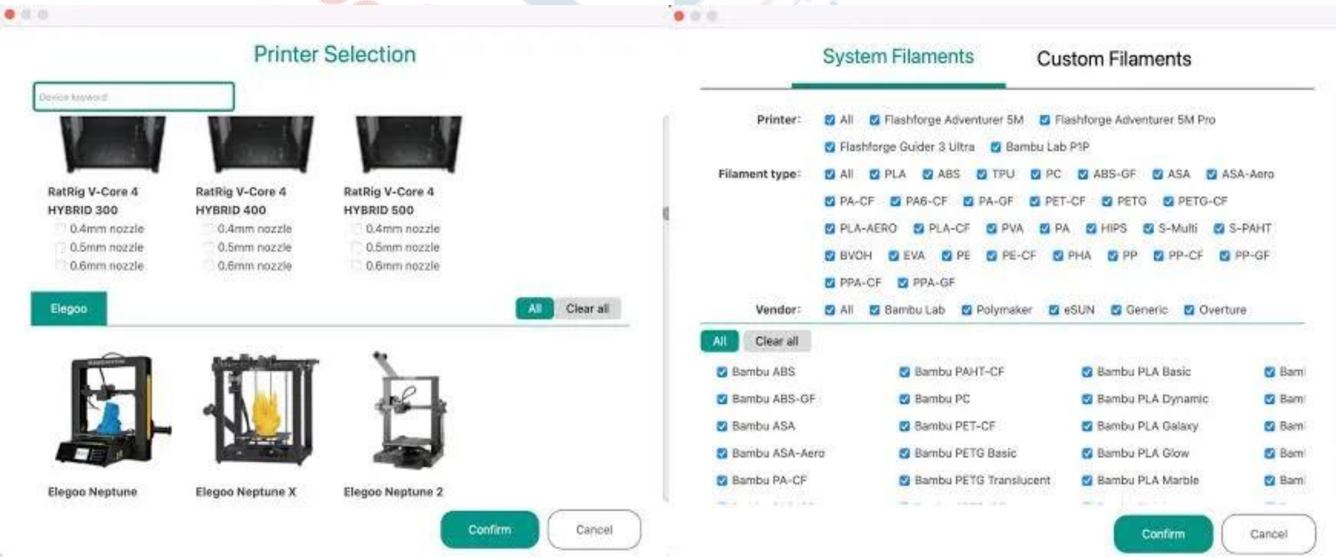

Figure 3. Material selection interface showing extensive filtering across printer compatibility, filament types, and vendors in Orca slicer interface

The multi-dimensional filtering system requires users to navigate technical classifications without contextual explanation, highlighting the need for adaptive visual guidance in material selection workflows.

Table 1. Comparison of free slicer software based on visual complexity and AI support potential

Slicer Software	Visual Density / Complexity Level	Key Visual Characteristics	Cognitive Load Level	AI Support Potential
Cura	Moderate	Multiple panels, contextual menus, layered previews, color-coded supports and infill	Medium	Adaptive highlighting and contextual parameter explanation
PrusaSlicer	High	Multi-mode UI (Simple/Advanced/Expert), dense parameter panels, detailed layer visualization	High in Expert Mode	Explainable AI overlays and dynamic prioritization of critical settings
SuperSlicer	Very High	Extensive granular controls, modifier meshes, complex infill visualization, numerous simultaneous parameters	Very High	AI-guided presets, noise reduction, critical parameter emphasis
IceSL	High	Dual interface (visual + scripting), procedural controls, dense visualization overlays	High	Context-aware translation between code and visual output
Slic3r	Moderate	Traditional parameter lists, less modern hierarchy, multiple tabs	Medium	Visual simplification and progressive disclosure
MatterControl	Low–Moderate	Cleaner layout, integrated design + slicing, reduced visual layering	Low–Medium	Adaptive interface scaling based on user expertise
AstroPrint	Low	Simplified cloud-based interface, limited preview depth	Low	Enhanced preview explanation and risk highlighting
3DPrinterOS	Low	Web-based interface, simplified controls with layered menus	Low	Automated contextual guidance for remote workflows

Conversely, interfaces that employed clear contrast, spatial grouping, and contextual annotations demonstrated higher interpretability. Users were better able to anticipate print outcomes and identify potential errors when visual cues aligned with real-world fabrication logic.

VI. DESIGN FRAMEWORK: AI-SUPPORTED VISUAL GUIDANCE

Each framework component responds directly to issues identified in the analysis. The framework operationalizes these findings through targeted visual interventions.

Table 2. Identified visual communication breakdowns and framework responses

No	Identified Issue	Framework Response
1	Excessive abstraction	Visual translation with contextual overlays
2	Weak hierarchy	Dynamic prioritization
3	Missing explanations	Explainable AI visualization
4	Cognitive overload	Adaptive disclosure

A. Framework Overview

The proposed framework translates analytical findings into a design model describing how slicer interfaces can support visual interpretation through adaptive guidance. Rather than introducing new functionality, the framework reorganizes how existing fabrication data is visually communicated to users. The model conceptualizes slicer interaction as a three-layer mediation process between computation and human understanding.

B. Framework Components

Table 3. AI - Supported visual guidance framework components

Section	Framework Component	Description
1	Rethinking the Slicer Interface	Slicer interfaces are reframed as visual communication systems mediating collaboration between users and computational intelligence.

Section	Framework Component	Description
2	Framework Overview	The framework consists of three layers: Data Interpretation, Visual Translation, and User Guidance.
3	Adaptive Visual Feedback	AI dynamically highlights critical regions to guide attention and reduce cognitive load.
4	Attention-Guided Interaction	Information is progressively revealed through guided inspection and contextual prompts.
5	Explainable AI Visualization	Automated recommendations are paired with visual reasoning cues to enhance transparency and trust.
6	Visual Hierarchy Reinforcement	Dynamic prioritization distinguishes critical information from secondary controls.
7	Human–AI Collaboration Implications	AI functions as a visual mediator supporting informed user decision-making rather than replacing human agency.

C. Framework Structure (Three-Layer Model)

Layer 1 - Data Interpretation

- Computational analysis of geometry, parameters, and risk conditions.
- AI identifies regions requiring user attention.

Layer 2 - Visual Translation

- Data transformed into interpretable visual cues:
  - hierarchy reinforcement
  - contextual annotations
  - explainable overlays

Layer 3 - User Guidance

- Interface adapts presentation based on workflow context:
  - progressive disclosure
  - attention guidance
  - reasoning feedback

VII. LIMITATIONS AND FUTURE WORK

The study is limited by its qualitative scope and absence of empirical user testing. Future research may include usability experiments, prototype implementation, expanded platform comparison, and real-time adaptive visualization studies.

VIII. DISCUSSION

The findings suggest that contemporary slicer interfaces prioritize computational completeness over perceptual clarity. While detailed data is available, it is not always communicated in ways that align with users' visual literacy levels. This shifts cognitive burden onto users, particularly novices and interdisciplinary practitioners, revealing a gap between automation capabilities and human interpretability. AI-driven adaptation offers a pathway toward addressing this gap. By learning from user behavior and print outcomes, slicer interfaces can adjust visual complexity, emphasize relevant information, and provide just-in-time explanations. Importantly, such systems should support—not replace—user judgment, maintaining agency while reducing ambiguity.

IX. CONCLUSION

This study underscores the importance of visual literacy in digital fabrication workflows. As slicer software continues to evolve through automation and artificial intelligence, its success will depend not only on technical optimization but also on effective visual communication. Treating slicer interfaces as design systems opens new pathways for enhancing user understanding, reducing errors, and fostering trust in automated fabrication processes. Future fabrication systems may therefore function not only as execution tools but as intelligent visual collaborators supporting interpretation, learning, and trust in automated production.

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