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A comprehensive usability study of 3D printing slicer software: Integrating SUS, USE questionnaire, and key UX dimensions

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ABSTRACT

This study evaluates the usability of three widely used 3D printing slicer software, Ultimaker Cura, IdeaMaker, and PrusaSlicer, at the Engineering Drawing Laboratory of UPN "Veteran" Yogyakarta. A mixed-methods approach was applied, combining the System Usability Scale (SUS) and the USE Questionnaire (Which Assesses Usefulness, Ease of Use, Ease of Learning, and Satisfaction), as well as direct observation of three UX dimensions: learnability, effectiveness, and efficiency. Nine respondents completed seven task scenarios, each with six repetitions. To compare the three software, statistical analysis was conducted using the Friedman test and Wilcoxon post-hoc comparisons. The results showed that Ultimaker Cura consistently achieved the highest SUS and USE scores and demonstrated significantly faster task completion times. The strong alignment between observed performance and user perception supports the validity of the blended evaluation method. This study concludes that Ultimaker Cura is the most user-friendly option for beginners and is well-suited for educational environments. This finding contributes to provide guidance in selecting software and teaching practices in educational laboratories, while also contributing to usability research.

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1. INTRODUCTION

Additive Manufacturing (AM) is a process of making products by adding material layer by layer until it becomes the desired product [1]. Thanks to its ability to produce products with a high level of complexity in a relatively shorter production time when compared to conventional methods, AM has become a technology that has received great attention in the manufacturing industry [2]. AM and 3D printing are often thought of as similar terms, but there is actually a fundamental difference between the two. AM is a broader concept that encompasses all manufacturing techniques that use the "adding materials" approach, while 3D printing is a subcategory of AM that refers to the layer-by-layer printing process using 3D printing technology.

In recent years, 3D printing has become an important part of various fields such as manufacturing, healthcare, education, as well as prototyping, so the demand for more user-friendly and efficient software is increasing. There are several types of software commonly used in the 3D printing process with their respective functions, including slicer software. Slicer is software used to convert 3D models (usually in STL, OBJ, or 3MF format) into machine instructions (G-code) that can be read and executed by a 3D printer. Its main functions are (1) dividing the model into horizontal layers to be printed one by one; (2) setting print parameters such as speed, nozzle and bed temperature, layer height, infill, and others; (3) generating nozzle and extruder motion paths in the form of G-code; and (4) simulating and previewing the printed results, so that users can check for errors or estimate time and materials before printing.

The use of 3D printing technology in the learning process in higher education has become an increasingly popular trend due to its potential to improve the quality and learning experience of students. 3D printing allows students to print real objects from digital designs that have been created and enables students to better understand concepts studied in fields such as engineering, product design, art, and medicine [3]. With 3D printing, students can see and touch physical models of complex or abstract products, which helps clarify their understanding. In addition, the use of 3D printing can also motivate students to study harder, because students can see the concrete results of their efforts and thoughts. This can create a more interactive learning environment, thus improving the quality of education and students' future career preparation.

The Engineering Drawing Laboratory of the Industrial Engineering Department of UPN "Veteran" Yogyakarta is one of the laboratories that has integrated AM technology into its learning process. There are two types of 3D printing machines used to directly apply the concepts learned in product design and manufacturing, namely Ender-3 and Haltech H-01. Despite the great potential it offers [4], [5] the usability of slicer software is often a secondary concern. Since 3D printing is now accessible to anyone, the need for a slicer software interface that is easy to learn effectively and efficiently is urgent. Evaluating the usability of 3D printing software is an important step to identify problems that may arise during the use of the software.

Usability evaluation in software engineering has evolved into a process conducted with a scientific approach by following the ISO 9241-11 standard, which defines usability through the dimensions of effectiveness, efficiency, and satisfaction [6]. In addition, user experience (UX) dimensions such as learnability, satisfaction, and task load are increasingly considered in modern interface design to improve the comfort and efficiency of user interaction [7], [8]. Instruments such as the System Usability Scale (SUS), introduced by Brooke, have become a widely accepted tool for quick and lightweight usability assessment across multiple domains [9]. In recent years, researchers have also applied these instruments for retrospective usability assessment across various products and software categories [10]–[12], with further supporting studies emphasizing their adaptability and reliability in diverse evaluation contexts [13], [14], [15], [16]. Besides SUS, another widely used instrument is the USE Questionnaire, which is designed to evaluate usability based on four main dimensions: Usefulness, Ease of Use, Ease of Learning, and Satisfaction [13], [17]. This instrument provides a more detailed view of user perception and has been applied across various domains such as mobile applications, digital health systems, and online education [18], [19]. In this study, the USE questionnaire is not used to replace broader UX concepts but to complement them. While UX represents a holistic experience, including emotional, cognitive, and task-related aspects, our focus is on three measurable UX dimensions relevant to novice interaction: learnability, effectiveness, and efficiency. Thus, the combination of SUS, USE, and UX dimensions allows us to examine both perceived usability (what users feel) and actual user performance (what users do). However, to date, very few studies have integrated these three perspectives specifically for evaluating 3D printing slicer software [20], [21].

Despite the availability of advanced software slicers such as Cura, PrusaSlicer, and IdeaMaker, there is no comprehensive usability evaluation based on a standardized framework. The previously described literature has emphasized usability scores with the SUS and Usefulness, Satisfaction, and Ease of Use (USE) questionnaires, which are widely adopted in usability research. However, there is still debate about whether such versatile tools can fully capture usability value in specialized applications such as slicer software.

This study aims to fill that gap by evaluating the usability of Cura, PrusaSlicer, and IdeaMaker slicer software that are actively used in the Engineering Drawing Laboratory of the Industrial Engineering Department of UPN "Veteran" Yogyakarta. This evaluation combines three complementary methods: the SUS scale, the USE Questionnaire, and task-based usability testing focusing on learnability, effectiveness, and efficiency. Together, these methods allow the study to capture both perceived usability (how users rate the software through standardized questionnaires) and actual user performance (how well users complete tasks while operating the slicer). By triangulating these approaches, the study sought to uncover not only how easy the tool is to use, but also why certain features enhance or hinder usability. The findings aim to inform software selection and teaching practices in educational laboratories while contributing to broader usability research in specialized technical domains.

This research offers the following key contributions:

1) This study presents a comprehensive usability evaluation of three popular 3D printing slicer software, Ultimaker Cura, IdeaMaker, and PrusaSlicer, using a combination of SUS, USE Questionnaire, and direct observation of user performance.
2) It introduces an integrated approach to usability testing that combines subjective user perception (through questionnaires) with objective performance data (such as task time and error rate), focusing on three key UX dimensions: learnability, effectiveness, and efficiency.
3) The study provides practical insights into which slicer software is most suitable for beginners in an educational setting, showing that Ultimaker Cura offers the best usability based on both user feedback and task performance.
4) By filling the gap in usability-focused slicer comparisons, this research contributes to the development of more user-friendly interfaces for 3D printing software and offers guidance for educators in selecting the most appropriate tool for student use.

2. RELATED WORK

Usability testing of 3D printing slicer software is an important factor for novice users as the adoption of 3D printing among them is increasing. While this software plays a crucial role in converting 3D models into printer-ready instructions, the complexity of the interface and the large number of configuration parameters often pose a challenge to new users. As 3D printing adoption increases in educational and home environments, research has begun to highlight the need for more intuitive and non-technical user-friendly slicer software.

The existing literature (Table 1) is still dominated by comparisons of technical aspects, rather than systematic evaluations of usability. Several studies have compared various slicer software such as Cura, Simplify3D, PrusaSlicer, and Slic3r, with key focuses such as dimensional accuracy, surface finish, material consumption, and print time. For instance, Ariffin et al. [22] assessed Cura, Repetier-Host, and IdeaMaker based on dimensional accuracy and surface roughness, while Cahyati et al. [23] focused on filament material combinations with Cura, PrusaSlicer, and Repetier-Host, examining material efficiency and print quality, but did not assess usability. Šljivic et al. [24] analyzed different versions of Cura and PrusaSlicer based on print speed and accuracy, while Scherick et al. [25] compared CuraEngine and Slic3r in terms of dimensional accuracy and filament use, both studies lacking any focus on user experience. Li et al. [26] tested multiple unnamed slicers across different printers to evaluate print quality, but did not consider interface design or ease of use. Baumann et al. [27] highlighted the superior accuracy of Simplify3D and compared it with Cura and Slic3r, but again ignored usability factors. Lastly, Maideen et al. [28] conducted one of the earliest slicer comparisons, focusing on configuration settings and printed output, without addressing how beginners interact with the software. Overall, these studies contribute valuable technical insights but fail to address the usability challenges faced by novice users, an important gap that this research aims to fill.

Cura is often mentioned in several studies [22], [23] as the slicer software that offers the best balance between accessibility for beginners and decent technical performance, making it a popular choice for new users. In contrast, Simplify3D is recognized as superior in terms of dimensional accuracy and final part quality [24], although its interface is considered more complex.

Only a few studies have addressed usability from the perspective of beginner users. For example, Scherick et al. [25] introduced GaPA, a heuristic-based workflow designed to simplify slicing for novices, and Li et al. [26] surveyed home users to improve interface design. However, both lacked comparative evaluations using formal usability testing methods such as SUS or heuristic analysis.

In summary, while prior studies provide valuable insights into the technical capabilities of slicer software, they largely ignore usability concerns, particularly for novice users. This study aims to fill this gap by presenting a comparative usability evaluation between different slicer software for beginners, using systematic approaches such as usability testing, SUS, and the USE questionnaire. As such, this research brings together objective and subjective metrics to evaluate slicer software more thoroughly. Thus, this research not only expands the scope of slicer software evaluation but also makes a significant methodological contribution to the development of more friendly interfaces for new users.

Table 1. Literature review

Author	Year	Software Evaluated	Novice User Focus	Comparative Analysis	Usability Method Used
Scherick et al.[25]	2022	GaPA (Custom Tool)	✓		Heuristic-based workflow
Li et al. [29]	2019	Custom Design	✓		Survey & user feedback
Baumann et al. [27]	2016	Unnamed Slicers		✓	Not specified
Šljivic et al. [24]	2019	Simplify3D, Cura, Slic3r		✓	Not specified
Nr et al. [30]	2014	Multiple Slicers (Unnamed)		✓	Not specified
Ariffin et al. [22]	2018	CuraEngine, Slic3r		✓	Not specified
Maideen et al. [31]	2023	Cura 4.8, Cura 2.7, PrusaSlicer		✓	Not specified
Maideen et al. [28]	2025	Cura, PrusaSlicer, Repetier-Host		✓	Not specified
Bryła & Martowicz [21]	2021	Not named (via G-code output)		Implied	G-code analysis
Cahyati & Aziz [23]	2021	Cura, Repetier-Host, IdeaMaker		✓	Not specified
This research	2025	Cura, IdeaMaker, PrusaSlicer	✓	✓	SUS, USE Questionnaire, Observation

3. METHODS

This study employs three complementary usability evaluation approaches: task-based usability testing to measure learnability, effectiveness, and efficiency; the SUS to assess perceived usability; and the USE Questionnaire to evaluate perceived usefulness, ease of use, ease of learning, and satisfaction. Observations were conducted by asking each respondent to complete 7 predefined tasks (the list of tasks is in Figure 1) and repeated 6 times to measure stable performance. The observation phase measured three usability dimensions: learnability (how quickly users understood the software), effectiveness (tasks completed correctly), and efficiency (task completion time and number of errors). Tasks were performed sequentially, and participants were allowed to repeat previous steps only when necessary. A maximum time limit of five minutes was applied to maintain consistency while avoiding fatigue, and all task times and errors were recorded.

The task scenario in Figure 1 is fundamentally designed to follow a sequential order. If a user fails to complete a task, they will remain on that task until it is completed; the process does not automatically return to the previous stage. However, there is a possibility for users to manually go back to a previous task if they choose to repeat or correct something, but this is not a default system behavior. Therefore, the process flow in the diagram reflects the intended structure of the evaluation, where each task is performed step-by-step.

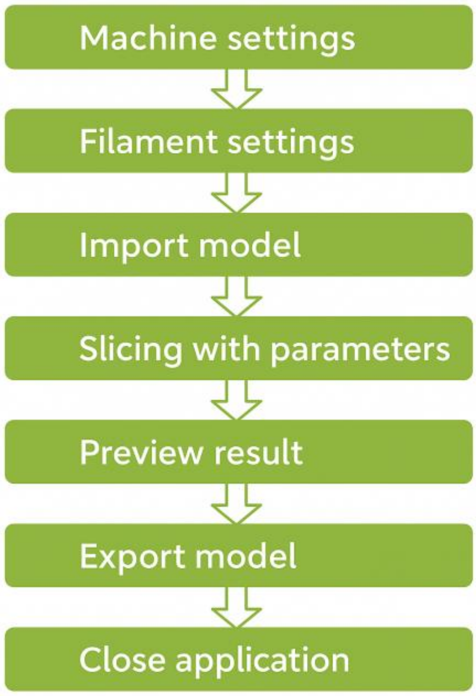


Figure 1. Task scenario

To support the assessment of effectiveness and maintain consistency across participants, a maximum time limit of five minutes was allocated for completing each task. This time frame aligns with usability testing guidelines, which recommend short, realistic task durations to prevent fatigue while still capturing meaningful performance data. Within this limit, the actual time spent on each task, along with the number of errors or repeated actions, was recorded to evaluate learnability, effectiveness, and efficiency.

After completing the tasks, respondents were asked to fill out SUS (10 questions) and USE (30 questions) questionnaires using a Likert scale of 1-5. Observations were used to measure the learnability dimension, the number of errors when performing tasks, and the efficiency of task completion time. Meanwhile, questionnaires were used to measure user perceptions of the usability of each software. The data was analyzed quantitatively using SUS score calculation and answer distribution on the USE questionnaire, and combined with qualitative observation results.

All quantitative data were analyzed using within-subject statistical tests because each participant used all three slicer software. For SUS, USE dimensions, task time, and error counts, we first computed descriptive statistics (mean, standard deviation, and 95% confidence intervals). To compare the three software, we applied the Friedman test, which is appropriate for non-parametric repeated-measures data. When the Friedman test showed significant differences, Wilcoxon signed-rank post-hoc tests with Bonferroni correction were used to identify pairwise differences. Effect sizes (Kendall's W for Friedman and r for Wilcoxon) were also reported to show the strength of the findings. These statistical procedures ensure that all interpretations are supported by robust quantitative evidence.

The participants in this study consisted of 9 Engineering Drawing laboratory assistants as novice users of 3D printing software and was conducted at the Engineering Drawing Laboratory, Industrial Engineering Department, UPN "Veteran" Yogyakarta. Novice users were chosen because slicer software is often introduced to students and new users in laboratory environments, where usability challenges are most apparent. Evaluating beginners allows the study to capture issues related to learnability, clarity of interface, and early-stage task performance—factors that may not be visible when testing with expert users. Although the number of participants in this study was limited to nine people, this approach remains methodologically valid for formative usability evaluation. Some studies state that 5 to 10 respondents are sufficient to identify most relevant usability issues [32]–[34]. In contrast, UX studies that aim to measure broader experiential aspects often require larger samples. In this research, the primary focus is usability testing, supported by SUS, USE, and task-based measures; therefore, Nielsen's guideline is considered appropriate. The goal is not to generalize population-level UX metrics, but to identify usability problems encountered by novice users when interacting with slicer software. In addition, the data in this study was reinforced by task repetition, quantitative measurements through SUS and USE, as well as direct observation, so that the findings remain representative for the educational laboratory context. The main objective of the data collection was to evaluate the user experience when using three commonly used slicer software in the laboratory, namely Ultimaker Cura, IdeaMaker, and PrusaSlicer.

4. RESULTS AND DISCUSSION

4.1. SUS score

The SUS consists of 10 items rated on a 1–5 Likert scale and converted into a final score from 0–100. Table 2 presents the descriptive statistics of SUS scores for the three slicer software.

Table 2. Descriptive statistics of SUS scores

Software	Mean SUS	SD	95% Confidence Interval (CI)
Cura	70.83	8.86	[63.40, 78.27]
IdeaMaker	53.61	13.4	[42.49, 64.73]
PrusaSlicer	47.11	8.94	[39.58, 54.64]

Based on the interpretation of the SUS standard [35], [36], which can be seen in Figure 2, interpreting SUS scores can be challenging because different SUS interpretation models, such as grade scale, adjective rating, and acceptability range—do not always align perfectly. For example, a single SUS score may fall into a "D" grade on the curved grading scale, yet be labeled "OK" on the adjective rating scale. Following the recommendations of Bangor et al. [35] and Sauro & Lewis [36], this study interprets SUS results by considering all three interpretations together rather than relying on only one scale, allowing a more balanced understanding. To avoid misinterpretation, the study does not use the SUS grade scale in isolation; instead, it triangulates acceptability ranges, adjective ratings, and grade interpretations to form a consistent and meaningful conclusion about each slicer's usability.

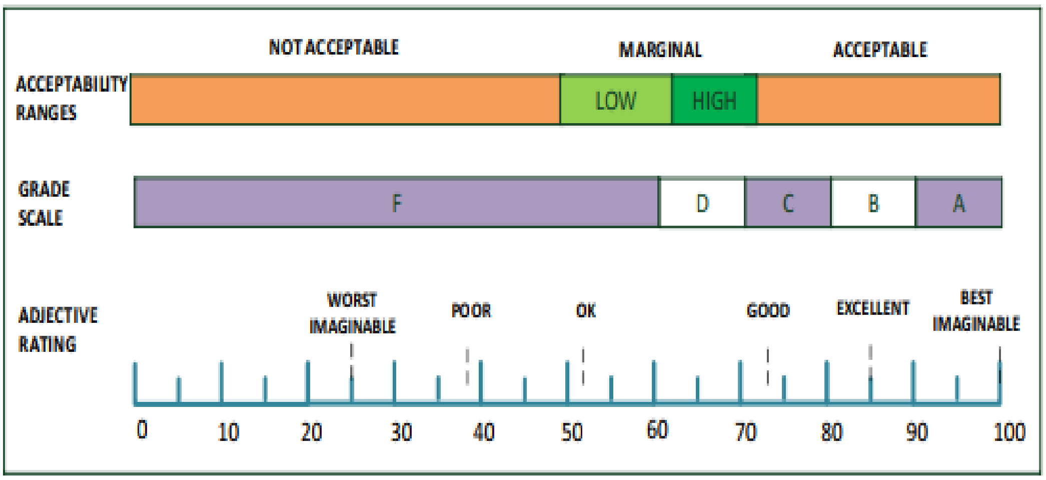


Figure 2. Interpretation scale of SUS score [34], [35]

From Table 2, we know that Cura's score (70.83) consistently falls within the "Acceptable" range and near the boundary between "Good" and "OK," indicating that most respondents were comfortable using it. IdeaMaker (53.61) is positioned in the "Marginal" range, which corresponds to "OK" on the adjective scale but below average in the grade scale, suggesting that its usability is adequate but still requires improvement, particularly in ease of use. PrusaSlicer (47.11) lies in the "Not Acceptable" region and near the lower adjective bands, indicating that novice users found it difficult to operate. These interpretations are aligned with the USE Questionnaire results, which provide additional evidence about perceived usefulness, ease of learning, and satisfaction.

4.2. USE questionnaire evaluation

The USE questionnaire was used to evaluate four usability dimensions—Usefulness, Ease of Use, Ease of Learning, and Satisfaction—across the three slicer software. Respondents rated 30 items on a 1–5 Likert scale, and the descriptive results are shown in Table 3, Table 4, and Table 5 .

Table 3. USE score of ultimaker cura

No	Usability Dimensions	Valid Item Count	Max. Score	Observe Score	%	Average
1	Usefulness	8	480	404	84.17%	4.21
2	Ease of Use	11	660	530	80.30%	4.02
3	Ease of Learning	4	240	200	83.33%	4.17
4	Satisfaction	7	420	348	82.86%	4.14
	Total	**30**	**1800**	**1482**		
		Average			**82.67%**	**4.13**

Table 4. USE score of ideamaker

No	Usability Dimensions	Valid Item Count	Max. Score	Observe Score	%	Average
1	Usefulness	8	480	347	72.29%	3.61
2	Ease of Use	11	660	425	64.39%	3.22
3	Ease of Learning	4	240	159	66.25%	3.31
4	Satisfaction	7	420	277	65.95%	3.30
	Total	**30**	**1800**	**1208**		
		Average			**67.22%**	**3.36**

Table 5. USE score of prusaslicer

No	Usability Dimensions	Valid Item Count	Max. Score	Observe Score	%	Average
1	Usefulness	8	480	375	78.13%	3.91
2	Ease of Use	11	660	460	69.70%	3.48
3	Ease of Learning	4	240	171	71.25%	3.56
4	Satisfaction	7	420	314	74.76%	3.74
	Total	**30**	**1800**	**1320**		
		Average			**73.46%**	**3.67**

Based on Table 3, Ultimaker Cura achieved the highest scores across all dimensions, with an average rating of 4.13 (82.67%). The strongest dimensions were Usefulness (84.17%) and Ease of Learning (83.33%), indicating that users found Cura highly functional and easy to understand from the beginning.

Based on Table 4, IdeaMaker showed moderate usability, with an average score of 3.67 (73.46%). Its highest-performing dimensions were Usefulness (78.13%) and Satisfaction (74.76%), suggesting that users considered it helpful and reasonably pleasant to use, although some aspects—particularly Ease of Use—were less intuitive.

Based on Table 5, PrusaSlicer recorded the lowest overall performance, with an average score of 3.36 (67.22%). All dimensions fell below 73%, and Ease of Use (64.39%) was the weakest area. This indicates that novice users experienced difficulty navigating and interacting with PrusaSlicer compared to the other two software.

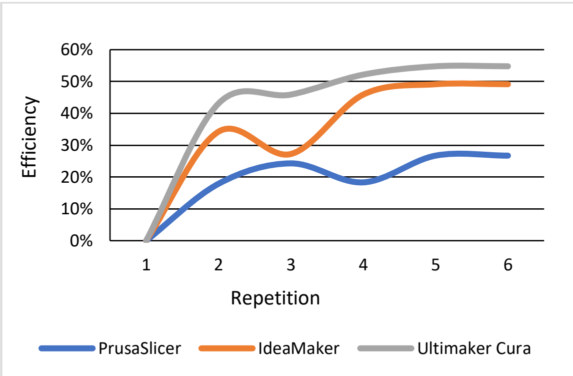
Table 6 further supports these findings through descriptive statistics of each USE dimension. Cura consistently achieved the highest mean scores with narrow confidence intervals, while IdeaMaker and PrusaSlicer showed lower ratings and greater variability. These patterns align with the SUS results and reinforce that Cura provides the most favorable usability experience for novice users.

Table 6. Descriptive statistics of USE dimensions

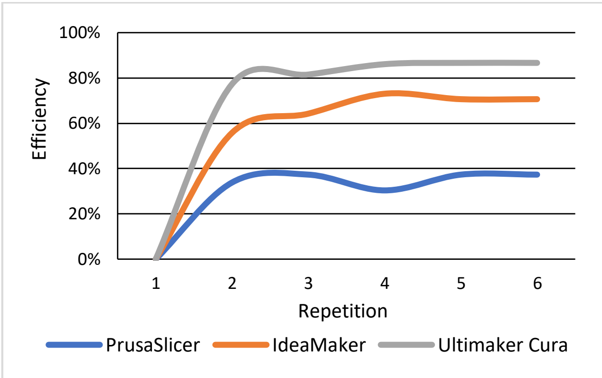
Usability Dimensions	Software	Mean	SD	95% CI
Usefulness	Cura	4.39	0.52	[4.00, 4.77]
	IdeaMaker	4.03	0.64	[3.53, 4.53]
	PrusaSlicer	3.63	0.72	[3.05, 4.20]
Ease of Use	Cura	3.93	0.78	[3.37, 4.49]
	IdeaMaker	3.40	0.53	[3.02, 3.78]
	Cura	3.32	0.51	[2.95, 3.69]
Ease of Learning	Cura	4.36	0.56	[3.93, 4.78]
	IdeaMaker	3.53	0.53	[3.15, 3.91]
	PrusaSlicer	3.42	0.54	[3.03, 3.81]
Satisfaction	Cura	4.22	0.53	[3.83, 4.61]
	IdeaMaker	3.73	0.53	[3.34, 4.11]
	PrusaSlicer	3.20	1.04	[2.41, 3.98]

4.3. UX dimensions evaluation

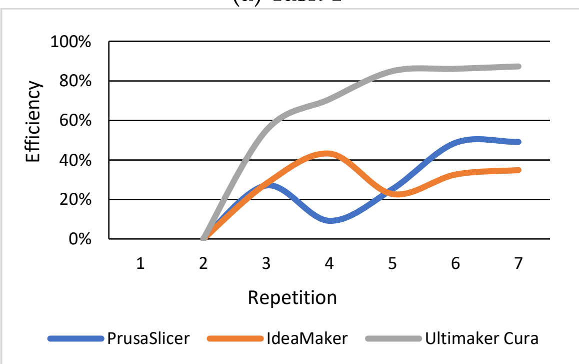
The UX evaluation focuses on learnability, effectiveness, and efficiency based on users' performance across seven repeated tasks. Figure 3 shows the learning curves for each task. Overall, Ultimaker Cura demonstrated the fastest and most consistent improvement, particularly in early tasks such as machine setup (Task 1), filament setting (Task 2), and model import (Task 3). IdeaMaker showed moderate improvement, with stable performance after several repetitions, while PrusaSlicer exhibited slower and more fluctuating learning patterns, indicating a steeper learning curve for novice users.



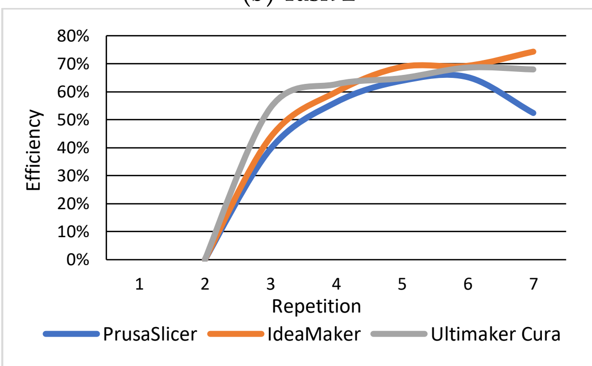
(a) Task 1



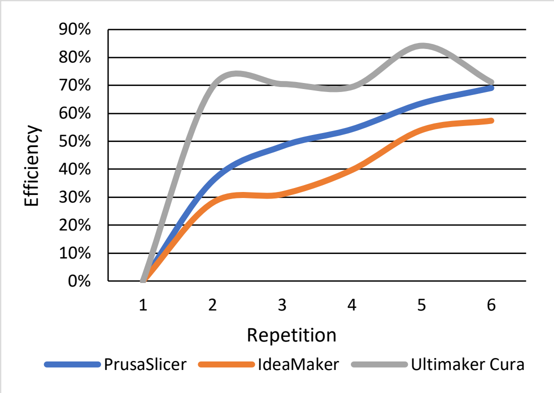
(b) Task 2



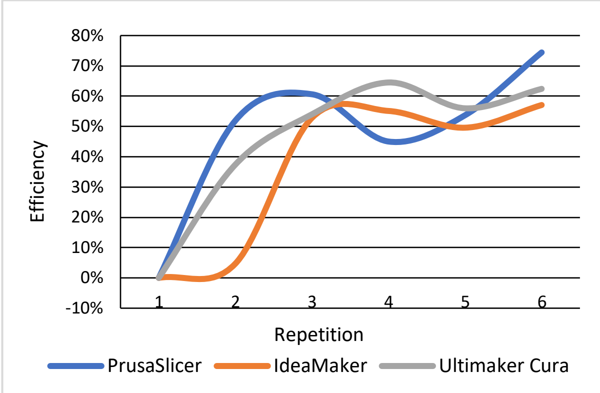
(c) Task 3



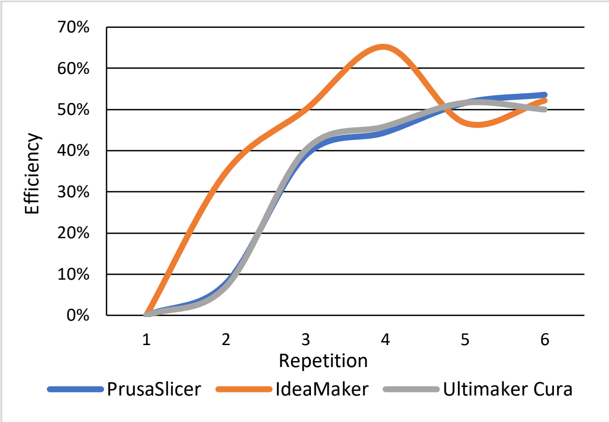
(d) Task 4



(e) Task 5



(f) Task 6



(g) Task 7

Figure 3. The learning curve of each task and each software

In terms of effectiveness (Figure 4 and Figure 5), all three software eventually reached 100% task completion across repetitions. However, initial differences were observed: IdeaMaker achieved perfect effectiveness earlier in Tasks 2 and 3, suggesting that some interfaces were easier for beginners to interpret. Cura and PrusaSlicer started with lower initial effectiveness in several tasks but improved rapidly and reached full completion within four to five iterations.

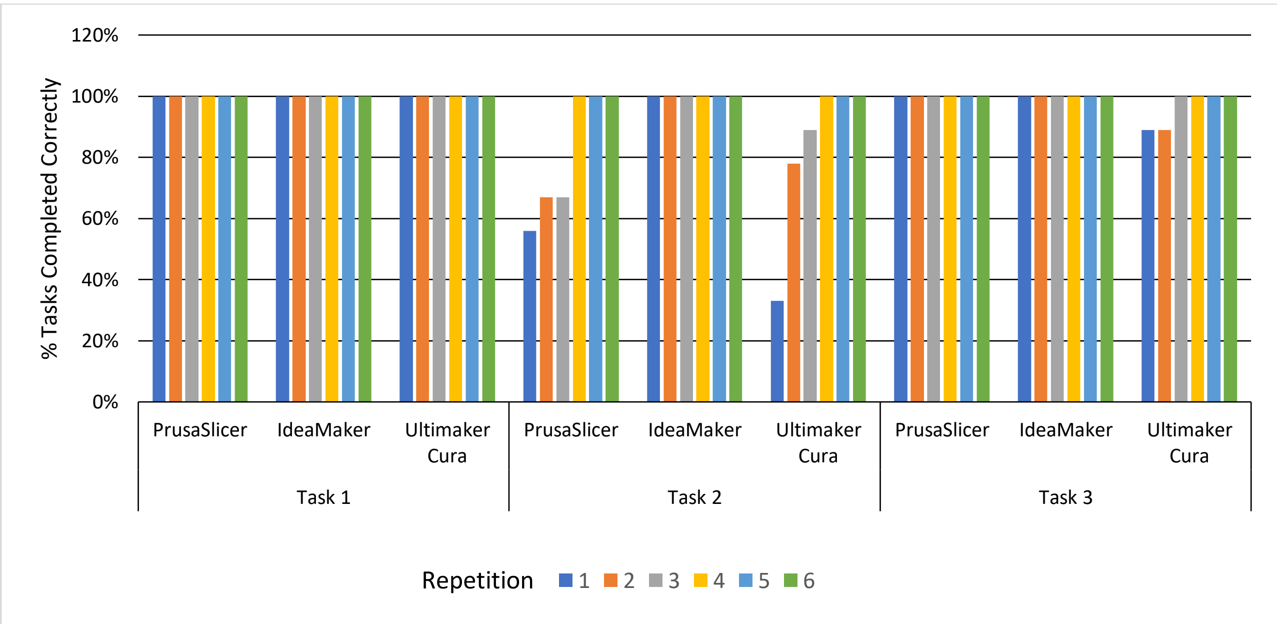


Figure 4. Percentage of tasks completed correctly for task 1 to task 3

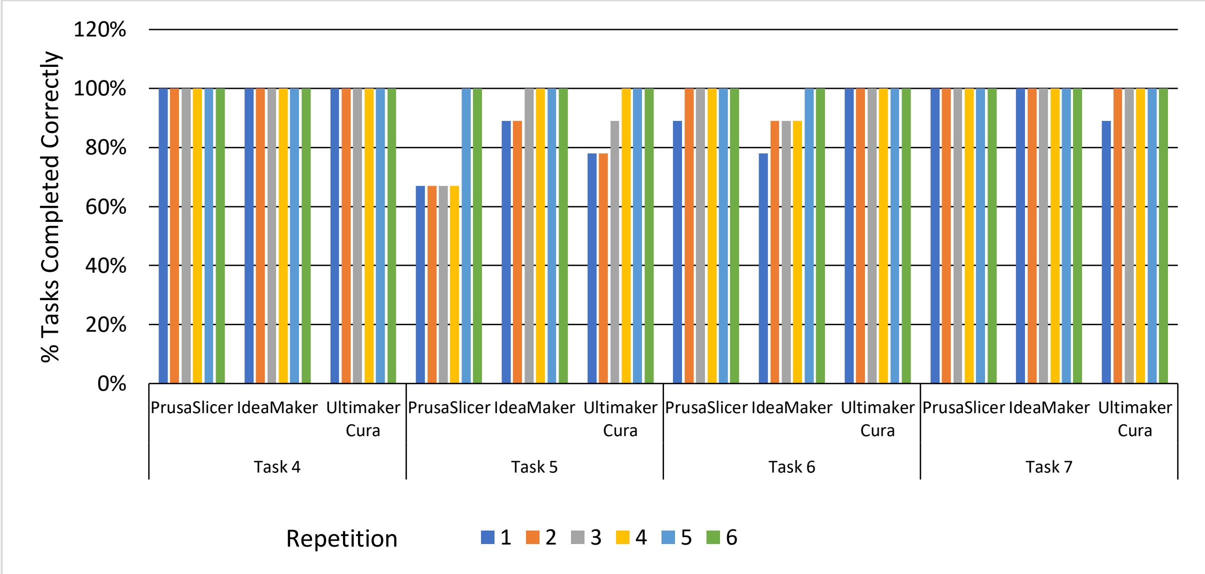
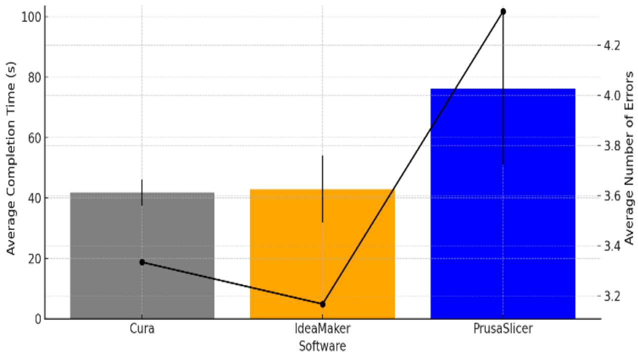
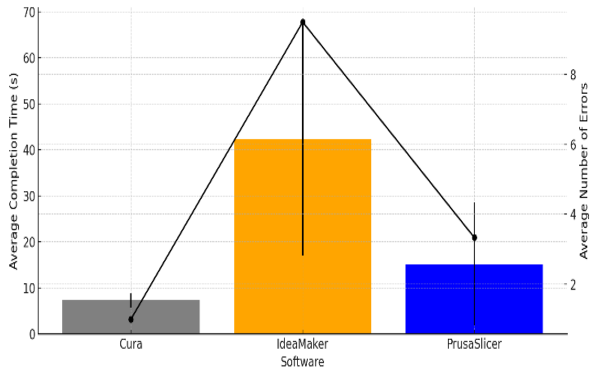


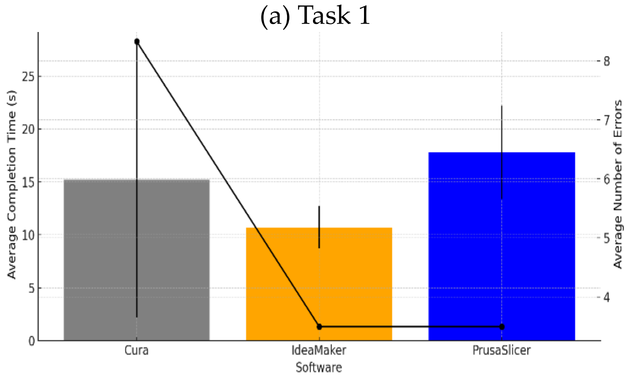
Figure 5. Percentage of tasks completed correctly for task 4 to task 7



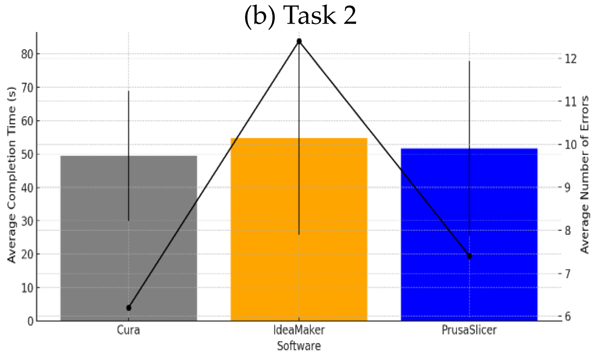
(a) Task 1



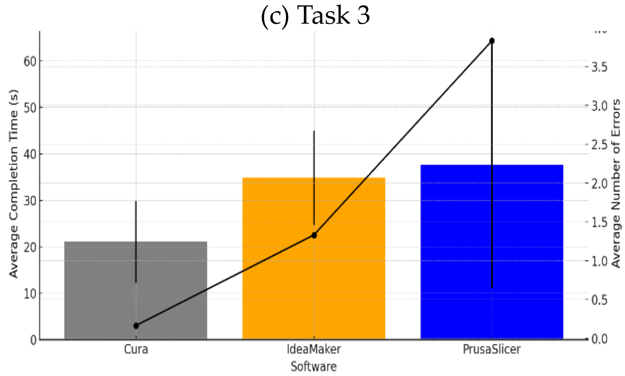
(b) Task 2



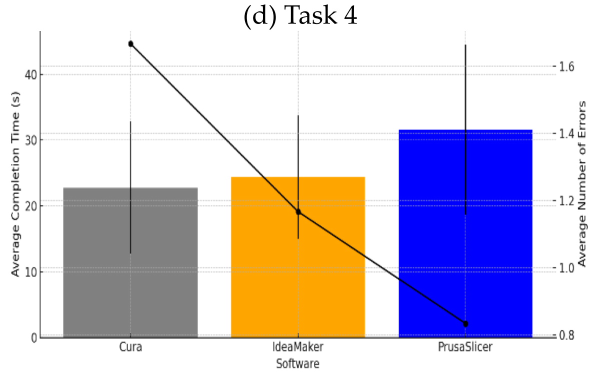
(c) Task 3



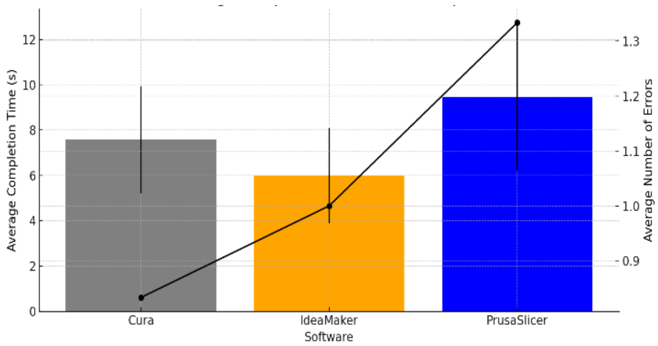
(d) Task 4



(e) Task 5



(f) Task 6



(g) Task 7

Figure 6. Average completion time and error per software

Efficiency results, summarized in Figure 6, Table 7, and Table 8 show clearer performance differences. Cura achieved the fastest average completion time across all tasks (22.01 s), followed by IdeaMaker (34.80 s) and PrusaSlicer (46.07 s). Despite similar error rates among the three software (0.49–0.58 errors on average), time-based efficiency revealed meaningful gaps, Cura consistently enabled quicker task execution, while PrusaSlicer required substantially longer times, especially in early repetitions.

Overall, the UX analysis indicates that Cura offers the best balance of learnability, effectiveness, and efficiency, allowing users to improve quickly and complete tasks with minimal difficulty. IdeaMaker performs reasonably well, though less efficiently than Cura, while PrusaSlicer shows the slowest improvement and requires more user adaptation, particularly for novice users.

Table 7. Descriptive statistics for task completion time per software (n = 9, 7 tasks)

Software	Mean Time (s)	SD	95% CI
Cura	22.01	6.81	[16.77, 27.25]
IdeaMaker	34.80	14.68	[23.52, 46.08]
PrusaSlicer	46.07	22.80	[28.54, 63.60]

Table 8. Descriptive statistics for number of errors analysis (7 Tasks Combined, n = 9)

Software	Mean Errors	SD	95% CI
Cura	0.49	0.32	[0.27, 0.71]
IdeaMaker	0.58	0.45	[0.25, 0.91]
PrusaSlicer	0.49	0.38	[0.20, 0.77]

4.4.Cross-method comparison and overall interpretation

The results from SUS, the USE questionnaire, and UX performance measures consistently show that Ultimaker Cura provides the best overall usability among the three slicer software tested. As shown in Table 9, Cura achieved the highest SUS score (70.83) and the highest USE score (82.67%), indicating strong perceived usability, usefulness, ease of learning, and satisfaction. IdeaMaker ranked second with moderate usability scores, while PrusaSlicer received the lowest ratings, reflecting greater difficulty for novice users.

Table 9. Usability evaluation result

Software	SUS Score	USE Questionnaire Score	Rank
PrusaSlicer	47.29	67.22%	3
Cura	70.83	82.67%	1
IdeaMaker	54.38	73.46%	2

Table 10 summarizes the statistical comparison across all usability dimensions. Significant differences were found in SUS, most USE dimensions, and task completion time, with Cura outperforming the other software in nearly every category. Cura was significantly more usable (SUS), more useful, easier to learn, more satisfying, and significantly faster in task completion time compared to IdeaMaker and PrusaSlicer. IdeaMaker consistently occupied the middle position without significant advantages over Cura. PrusaSlicer ranked lowest in learnability and efficiency, although its error rate was not significantly different from the others.

Table 10. Summary of Friedman Tests and Post-hoc Wilcoxon results for all dimensions (n = 9)

Measure	Friedman $\chi^2(2)$	p-value	Kendall's W	Significancy	Post-hoc (Bonferroni α = .0167)	Interpretation
SUS Score	14.11	< .001	0.78 (large)	Yes	Cura > Idea (p=.008), Cura > Prusa (p=.008), Idea vs Prusa = n.s.	Cura significantly most usable
USE – Usefulness	10.22	.006	0.57 (moderate–large)	Yes	Cura > Prusa (p=.008), others n.s.	Cura strongest usefulness
USE – Ease of Use	7.44	.024	0.41 (moderate)	Yes	All pairwise = n.s.	No significant differences
USE – Ease of Learning	12.11	.002	0.67 (large)	Yes	Cura > Idea (p=.008), Cura > Prusa (p=.008)	Cura easiest to learn
USE – Satisfaction	10.89	.004	0.61 (large)	Yes	Cura > Prusa (p=.008), others n.s.	Cura most satisfying
Task Completion Time	14.00	≈ .001	0.78 (large)	Yes	Cura faster than Idea (p=.009) & Prusa (p=.009)	Cura significantly fastest
Number of Errors	2.44	.295	0.14 (small)	No	All pairwise = n.s.	No difference in error rates

The cross-method comparison revealed strong consistency between subjective perceptions and objective performance. In the learnability dimension, Ultimaker Cura showed the steepest and most stable learning curve. In almost all tasks, Cura showed a rapid increase in efficiency, as seen in Tasks 1 and 2 where efficiency reached more than 50% in just two to three repetitions. This is in line with the Ease of Learning score on the USE Questionnaire for Cura, which reached 83.33% (average 4.17), the highest compared to the other two software. Thus, the quantitative results of the questionnaire support the observational findings that Cura is the easiest to learn for novice users. In contrast, IdeaMaker showed a fairly good efficiency curve at the beginning but stagnated in some tasks, as well as inconsistencies in tasks such as Task 3 (import model) and Task 5 (preview). This is reflected in the Ease of Learning score of 66.25% (average 3.31), which is a medium value. Although users can complete tasks correctly, the learning process to master the workflow is not as fast as Cura. PrusaSlicer, on the other hand, shows a slow learning curve, with low efficiency in initial tasks such as Task 1 (28%) and Task 2 (40%). This is in accordance with the Ease of Learning results in the USE Questionnaire which only reached 71.25% (average 3.56). Although not as low as IdeaMaker in this score, the user adaptation process to PrusaSlicer is slower due to its relatively complex and feature-dense interface.

Efficiency in UX Dimensions is measured through task completion time and number of errors. In contrast, the Ease of Use dimension in the USE Questionnaire represents a subjective assessment, capturing how easy users felt the software was to operate. While these two aspects measure different things—objective performance vs. subjective perception—they are complementary. Novice users may require more cognitive effort, yet their perceptions remain important because slicer software in educational settings is primarily used by beginners. Therefore, subjective "easiness" reported in the USE Questionnaire reflects how approachable the interface feels to users with limited prior experience. For Ultimaker Cura, users completed tasks quickly and made relatively few errors, and this aligns with its high Ease of Use score (80.30%, mean

4.02). This suggests that beginners not only performed well but also felt the software was easy to understand. IdeaMaker's Ease of Use score (64.39%, mean 3.22) corresponds with fluctuating efficiency results, especially in early steps such as filament setting, indicating that users needed more cognitive effort even though tasks were eventually completed. PrusaSlicer's Ease of Use score (69.70%, mean 3.48) similarly reflects initial difficulty during early tasks; although performance improved in later steps, the early challenges shaped users' overall perception of how easy the software was.

Effectiveness measures the success of completing a task, while Satisfaction in the USE Questionnaire reflects the user's subjective satisfaction with the overall experience. The correlation between these two aspects is clear: users who successfully complete a task correctly tend to be more satisfied with the software. Ultimaker Cura, with high effectiveness from the start and stable efficiency, scored a Satisfaction score of 82.86% (mean 4.14), reflecting high satisfaction with the user experience. This is reinforced by the fast completion time and easy-to-access interface. IdeaMaker recorded a Satisfaction of 65.95% (mean 3.30). Despite its high effectiveness (100% from the start on some tasks), the slow completion time and high errors on some tasks affected the user's perception of comfort. PrusaSlicer scored a Satisfaction of 74.76% (mean 3.74). This score is higher than IdeaMaker, despite its lower initial effectiveness. This may be due to the sense of accomplishment that users feel after successfully conquering a steeper learning curve, resulting in increased satisfaction as mastery of the interface increases.

The relationship between the USE Questionnaire results and UX Dimensions suggests that users' perceptions tend to match their actual performance in completing tasks. When software provides an easy, fast, and error-free experience, users tend to give high scores on Ease of Use, Ease of Learning, and Satisfaction. These findings support the mixed-method approach to usability evaluation and reinforce the conclusion that Ultimaker Cura is the software with the best usability among the three tested, both from direct observation and user perception. Overall, the findings from the three usability evaluation methods (SUS, USE, and UX dimensions observations) consistently rank Ultimaker Cura as the software with the best usability, especially in terms of ease of learning and operational efficiency. IdeaMaker follows with fairly good performance and is suitable for general tasks, while PrusaSlicer, although initially challenging, has potential for further learning—especially for advanced users who need more flexibility and features.

The usability evaluation results show that Ultimaker Cura outperformed IdeaMaker and PrusaSlicer across almost all dimensions, including SUS score, USE questionnaire, learnability, efficiency, and task completion effectiveness. These findings align partially with previous studies such as Ariffin et al. [22] and Cahyati et al. [23], which also reported Cura's strong technical performance and ease of access for new users. However, unlike those studies which focused only on print quality and material use, this research adds a user-centered perspective by directly evaluating usability aspects with novice participants through standardized instruments and task-based testing.

In contrast to Šljivic et al. [24] and Scherick et al. [25], which emphasized speed and accuracy of sliced outputs, this study shifts attention to how users interact with the interface—an aspect often overlooked in prior works. Moreover, while Virzi et al. [32] and Faulkner [33] introduced user-friendly design ideas, they lacked formal comparative evaluation. This research addresses that gap by offering both subjective and objective usability comparisons among three major slicer tools in an educational setting.

5. CONCLUSION

This study provides a comprehensive usability evaluation of three popular 3D printing slicer software, Ultimaker Cura, IdeaMaker, and PrusaSlicer, by combining SUS and USE questionnaires with direct observation of task-based performance. Unlike previous studies that mainly focus on slicing quality or technical output, this research highlights how novice users actually interact with the software in an educational setting. The results clearly show that Ultimaker Cura offers the best overall usability. It achieved the highest SUS and USE scores and demonstrated significantly better performance across several statistical tests, including SUS, Ease of Learning, and task completion tim. These findings indicate that Cura is easier to learn, faster to use, and more satisfying for beginners compared to IdeaMaker and PrusaSlicer. IdeaMaker performed moderately well but showed lower ease of use, while PrusaSlicer required the most effort to learn, although user performance improved with repeated use. Across all methods, user perceptions were consistent with their actual performance: software that was easier and faster to operate also received higher usability ratings.

Despite these contributions, the study has several limitations. The number of participants was small and limited to a single academic environment, which may not represent all types of 3D printing users. Factors such as prior experience or individual learning styles were not explored in detail and may influence usability outcomes. Future research could involve a larger and more diverse group of participants, examine different usage contexts such as home or industrial environments, and include more advanced measurement tools like eye-tracking or cognitive load analysis. Overall, the findings offer useful guidance for educators and practitioners in selecting slicer software for beginners, and they emphasize the importance of designing interfaces that are intuitive, efficient, and supportive of new users.

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