ISSN 2723-6471

Quantitative Evaluation of Watercolor Brush Performance: A Comparative Study of User Satisfaction and Task Efficiency using 24 Innovative Brush Designs

Suraphan Chantanasut[1,*]

[1]*Department of Art Education, Faculty of Fine and Applied Arts, Rajamangala University of Technology Thanyaburi, 12110, Thailand*

(Received: September 7, 2024; Revised: October 13, 2024; Accepted: November 27, 2024; Available online: December 1, 2024)

Abstract

This study investigates the performance, user satisfaction, and durability of innovative watercolor brushes compared to traditional brushes, with a focus on quantifiable improvements. The innovative brushes, designed in collaboration with professional watercolorists, feature both round-handled and flat-handled versions aimed at enhancing painting comfort, precision, and control. The researcher created an innovative watercolor brush with a total of 24 types, divided into 12 round-handled brushes and 12 flat-handled brushes. A sample of 24 artists, including both professionals and amateurs, completed three distinct painting tasks—still-life, large-area washes, and detailed line work. Quantitative data on task completion times, paint usage, and durability were collected, alongside user satisfaction ratings for comfort, ease of use, and stroke control. Statistical analysis revealed that the innovative brushes significantly outperformed traditional brushes across all metrics. On average, the innovative brushes reduced task completion times by 13-15%, with a mean of 13.88 minutes compared to 15.89 minutes for traditional brushes on the still-life task. Paint usage was also lower, with innovative brushes using approximately 2.44 grams on average for the still-life task, compared to 2.97 grams for traditional brushes, reflecting a 17.8% improvement in paint efficiency. User satisfaction ratings were consistently higher for the innovative brushes, scoring an average of 4.5 out of 5 for comfort, ease of use, and stroke control, in contrast to 3.5 for traditional brushes. Durability assessments further showed that innovative brushes maintained an average bristle condition rating of 4.6 versus 3.5 for traditional brushes after extended use, confirming superior longevity. These results highlight the impact of ergonomic handle design and advanced synthetic materials on brush performance. Recommendations for future brush designs include further refinement of handle shapes and enhanced bristle technologies to support the technical and artistic needs of watercolorists. While limitations such as the subjective nature of user ratings and sample size should be noted, this study lays the groundwork for continued research on performance metrics for art tools across various creative disciplines.

Keywords: Watercolor Brushes, Task Efficiency, User Satisfaction, Ergonomic Design, Brush Durability

1. Introduction

Watercolor brushes have been integral to the evolution of watercolor painting since its origins in the 16th century, initially serving practical roles in documentation and later transforming into tools for artistic expression. Over time, artists developed specialized brushes to control watercolor's fluidity and transparency, blending traditional and Western techniques, as seen in China's adaptation during the late Qing Dynasty [1]. The expressive capabilities of watercolor brushes remain central to artistic practices, as they enable control over water and pigment, creating softness, transparency, and depth [2], [3]. Advances in brush design, driven by technological progress and artist collaboration, have pushed boundaries, blending traditional methods with digital innovations to expand artistic expression [4]. Collaborative efforts with world-class artists aim to enhance brush precision, comfort, and adaptability, ensuring these tools meet the evolving needs of contemporary painters experimenting with diverse techniques.

The collaboration with professional artists underscores a commitment to user-centered innovation in brush design, focusing on features such as brush shape, handle ergonomics, and bristle composition to enhance both comfort and control during extended use. By integrating new materials and exploring unique brush forms, the resulting tools offer precise strokes and better handling of watercolor properties, ensuring greater artistic flexibility. This approach merges

***Corresponding author: Suraphan Chantanasut (Suraphan_c@rmutt.ac.th)**
DOI: https://doi.org/10.47738/jads.v5i4.462

traditional craftsmanship with modern advancements to create brushes that meet high standards of performance and broaden creative possibilities within the medium. The introduction of 24 new brush designs, comprising 12 round-handled and 12 flat-handled brushes, represents a targeted effort to enhance painting comfort, precision, and control. Developed with input from professional watercolorists, these brushes address ergonomic and functional needs, aiming to improve the painting experience through better stroke control and reduced physical strain. The round-handled brushes prioritize comfort and versatility with their ergonomic design, facilitating a natural grip that reduces hand fatigue and allows for seamless transitions between broad strokes and fine lines [5]. Conversely, the flat-handled brushes offer enhanced stability and control, making them ideal for large washes and detailed line work, thanks to their broader grip surface [6]. Crafted with high-quality synthetic fibers that replicate the responsiveness and paint retention of traditional sable hair, these brushes provide smooth application and consistent performance. This material choice ensures shape retention and longevity, supporting artists' creative endeavors over time [7]. Overall, these innovative designs mark a significant advancement in watercolor brush development, enhancing both artistic expression and the physical experience of painting.

This research aims to quantitatively evaluate the performance of the 24 newly designed watercolor brushes, focusing on three key areas. First, task efficiency is assessed by measuring painting task completion times and paint usage. Second, user satisfaction is gauged through surveys examining comfort, ease of use, and stroke control, critical factors for artists engaged in prolonged painting sessions. Lastly, durability is evaluated by observing bristle wear and handle quality over repeated use, offering insights into the brushes' long-term resilience. This comprehensive approach seeks to provide a data-driven evaluation of their performance. The study is guided by three hypotheses. The first hypothesis (H1) proposes that innovative brushes enhance task efficiency, reducing completion times and optimizing paint usage compared to traditional brushes. The second hypothesis (H2) anticipates that artists will report higher satisfaction levels with the innovative brushes, particularly regarding comfort and ease of use due to ergonomic design enhancements. Finally, the third hypothesis (H3) suggests that innovative brushes will exhibit superior durability, maintaining bristle and handle quality after extensive use. Testing these hypotheses allows for a structured assessment of whether the new designs offer tangible improvements over traditional watercolor brushes.

2. Literature Review

2.1. Overview of Watercolor Brush Design

Watercolor brushes have traditionally been crafted using materials like natural hair (e.g., sable, squirrel) and synthetic fibers, each serving specific artistic purposes. Natural hair brushes are renowned for their water retention, flexibility, and precision, making them ideal for detailed work, while synthetic brushes offer durability and lower cost, providing a reliable option for artists [8], [9]. Despite their strengths, traditional brushes have notable limitations, including variability in natural hair quality, which can affect paint application and stroke precision. Over time, such brushes may lose their shape, resulting in reduced control. Additionally, traditional brushes often struggle with uneven paint distribution on textured surfaces due to their friction properties, leading to inconsistent results [8], [10]. Innovations in brush design have emerged to address these limitations. Polymer-based brushes have introduced engineered viscoelastic properties, enhancing control over paint application and improving adhesion to various surfaces [9], [11]. These modern brushes reduce material variability and offer consistent performance, excelling in water and pigment retention. This allows for versatility across techniques, from broad washes to fine details, reflecting a focus on precision and reliability in modern brush design [12]. As a result, contemporary artists gain improved confidence and control, enabling greater exploration of watercolor techniques.

2.2. Prior Studies on Art Tool Performance

The quantitative evaluation of artistic tools, including pens and brushes, encompasses user satisfaction, skill development, and performance outcomes. Various studies have highlighted how the design and functionality of artistic tools influence user experience, demonstrating that ergonomically designed tools with characteristics like optimal weight, balance, and tactile feedback can enhance artist satisfaction and engagement. Researchers have developed structured methodologies to measure skill development and user satisfaction by combining task difficulty with user performance. These methods provide a basis for evaluating tools in different artistic contexts, whether traditional or digital, and can be adapted for watercolor brushes by examining task efficiency, stroke accuracy, and user control

during painting. Additionally, cognitive aspects, such as mental engagement in art creation, further impact tool effectiveness. Despite extensive research on other artistic tools, specific studies on watercolor brushes remain scarce. Existing findings on ergonomic and functional aspects of tools like pens or general brushes do not fully capture the unique properties and user interactions associated with watercolor brushes. The limited quantitative data forces many artists to rely on anecdotal evidence and personal experience when selecting brushes, highlighting a research gap in understanding how different designs affect performance and satisfaction. Addressing this gap through rigorous, data-driven evaluations would provide valuable insights for artists, improving their choice of tools and enhancing their work. In contrast to fields like healthcare or toothbrush design, where tool effectiveness has been systematically evaluated, studies on watercolor brushes lack comparable quantitative assessments [13]. Methods from unrelated fields may offer a basis for developing a framework for brush evaluation, but must be adapted to account for watercolor painting's unique demands, such as water retention, precision, and stroke control. Tailored methodologies are essential to provide artists with reliable, data-based insights, ultimately improving their artistic performance and satisfaction with their tools.

2.3. Ergonomics and Usability in Creative Professions

The relationship between tool design—specifically weight, grip, and shape—and user comfort is pivotal in creative professions like painting, where tools are used for extended periods. Ergonomically designed watercolor brushes alleviate strain and enhance comfort, which directly influences an artist's efficiency and reduces the risk of musculoskeletal disorders (MSDs) [14]. Proper ergonomic handle design improves control, enabling more precise strokes while minimizing hand fatigue during long painting sessions [15]. Weight also significantly affects usability, as heavy brushes lead to fatigue, especially during repetitive or prolonged tasks. Research [16] shows that traditional designs often neglect ergonomics, increasing fatigue and discomfort, while lightweight, well-balanced tools reduce strain and offer better control. Handle weight and material selection further impact user satisfaction and performance, as emphasized by [17], highlighting that well-designed, lightweight brushes prevent cumulative strain injuries. Grip design is equally crucial; ergonomic handles tailored to hand contours reduce strain, improve grip strength, and enhance user comfort. Studies [18] show that optimal handle shapes reduce hand strain, improving comfort and performance, while [19] found that ergonomic handles promote efficient tool use by reducing grip force strain. This translates directly to improved artistry, as artists can focus on their work without discomfort.

2.4. Performance and Durability Metrics in Tool Evaluation

Performance and durability are critical metrics in tool evaluation across various industries, including industrial brushes and writing instruments. In industrial applications, brush performance is assessed through parameters like wear resistance, frictional heat generation, and task efficiency, such as sealing or cleaning. For instance, as noted by [20], the durability of brush seals is influenced by factors like bristle material and interactions with mechanical components, emphasizing the importance of material selection to minimize degradation over time. Similarly, [21] examined multi-stage brush seals' durability by evaluating their leakage performance and flow behavior, highlighting how these tools maintain their structural integrity under stress. These studies demonstrate the role of empirical testing and design optimization in enhancing tool longevity and performance. In writing instruments, performance evaluation often focuses on aspects like ink flow consistency, tip durability, and user satisfaction. Research by [22] highlighted the psychological component of perceived durability, showing that users' emotional connections to products can influence their perception of longevity. Writing tools are typically assessed through tests measuring both objective performance (e.g., consistent writing output) and subjective user feedback, providing a comprehensive understanding of durability. This dual approach ensures that tools perform well over time and maintain user trust and satisfaction. Adapting these methodologies to assess watercolor brushes involves examining factors such as bristle retention, paint flow, and resistance to repeated washing and drying. Just as industrial and writing tools are evaluated for durability and performance, watercolor brushes must maintain shape, bristle integrity, and paint application consistency over extended use. User feedback is equally essential, as it offers insights into practical performance in artistic settings. By integrating empirical tests with user satisfaction data, manufacturers can enhance watercolor brush design and longevity, meeting the high standards demanded by artists.

 ISSN 2723-6471

3. Methodology

3.1. Participant Selection and Grouping

For this study, 24 watercolor artists were selected, comprising an equal mix of 12 professional and 12 amateur painters, ensuring diversity in skill level and experience. Professionals had over five years of experience, while amateurs had less than five. Participants demonstrated familiarity with core watercolor techniques, such as washes, blending, and fine line work, to maintain task consistency. Recruitment was conducted through social media platforms like Instagram and Facebook, as well as outreach to local art schools, offering incentives such as free art supplies to encourage participation. Participants were randomly divided into two equal groups: the Traditional Brush Group, using conventional brushes, and the Innovative Brush Group, using newly designed brushes with 12 round-handled and 12 flat-handled variations. This balanced assignment, with both professionals and amateurs equally represented in each group, ensured fair comparisons. The randomization minimized potential biases, allowing for an objective evaluation of brush performance and user satisfaction, laying a solid foundation for the study's subsequent stages.

3.2. Task Design and Variable Definition

In this stage of the research, three specific painting tasks were designed to evaluate various aspects of watercolor brush performance, focusing on precision, control, paint retention, and ease of use. The tasks were chosen to reflect common techniques used by watercolor artists, ensuring that the brushes were tested in practical, real-world applications. The first task, still-life painting, was designed to test the brush's precision and control, requiring participants to replicate a detailed still-life image with intricate details, sharp lines, and layering techniques. The second task, a large-area wash, assessed the brush's ability to hold and distribute paint evenly across a broad surface, as participants created a smooth, gradient wash to evaluate paint retention and consistency. Lastly, the third task involved detailed line work, in which participants executed fine, controlled strokes to test the brush's handling of delicate, precise movements.

To support these tasks, the study utilized two distinct types of innovative brushes: round-handled and flat-handled designs. Each brush type was crafted to enhance comfort and control, addressing the specific demands of the tasks. The round-handled brushes, shown in figure 1, provide versatility, allowing for both broad strokes and intricate detail work due to their ergonomic grip.

Figure 1. Rounded-Handle Brushes

In contrast, the flat-handled brushes, displayed in figure 2 are designed for stability and consistent pressure application, making them ideal for tasks requiring extensive coverage or precise lines. The following figures provide a visual overview of these brush types, demonstrating the variety in shapes and sizes within each category, which are instrumental in assessing performance and user satisfaction across the different painting tasks.

 ISSN 2723-6471

Figure 2. Flat-Handle Brushes

For each task, specific measurement variables were defined to quantitatively and qualitatively assess the performance of both traditional and innovative brushes. The primary quantitative variables were task completion time and paint usage. Task time was measured using a stopwatch, tracking the duration of each task to assess the efficiency of the brush in handling the assigned techniques. Paint usage was measured by weighing the paint tubes before and after each task, providing a clear indication of how efficiently the brushes applied paint. These variables were essential in evaluating the brushes' functional performance, with shorter completion times and lower paint usage indicating higher efficiency and better paint retention.

In addition to the quantitative measurements, qualitative data was collected through post-task surveys completed by each participant. The survey focused on four key areas: comfort, ease of use, stroke control, and overall satisfaction. Participants rated each of these factors on a Likert scale from 1 to 5, allowing for a detailed understanding of their subjective experiences with the brushes. Open-ended questions were also included to gather more nuanced feedback, enabling participants to describe any specific challenges or positive experiences they had during each task. This qualitative data provided valuable insights into the user experience and complemented the quantitative findings by highlighting the areas where the innovative brush designs either excelled or fell short.

3.3.Experiment Execution

The experiment was conducted with meticulous preparation to ensure consistency and accuracy in data collection. All participants received identical materials—watercolor paper, paints, and palettes—with the only variable being the type of brush used, either traditional or innovative. Clear instructions were provided for three tasks: still-life painting, large-area washes, and detailed line work. Workspaces were set up in a controlled environment with consistent lighting and minimal distractions, and experiment supervisors monitored the process without intervening or providing feedback. Task times were precisely recorded using stopwatches, and paint usage was measured by weighing paint tubes before and after each task, capturing quantitative data accurately. Additionally, participants completed post-task surveys immediately after each task to gather qualitative feedback on brush performance, focusing on comfort, ease of use, stroke control, and overall satisfaction. Supervisors also visually inspected the brushes for bristle retention, shape maintenance, and handle wear using a brush condition evaluation form. This comprehensive data collection approach, combining task timing, paint usage, and participant feedback, provides robust data for the subsequent analysis phase, enabling a thorough comparison between traditional and innovative brushes.

3.4. Data Collection and Organization

Upon completion of this stage, both quantitative and qualitative data were meticulously organized into spreadsheets. Task completion times and paint usage for all 24 participants across the three tasks were recorded, with each participant’s data carefully reviewed to flag any discrepancies, such as unusually long task times or variations in paint usage. This structured overview provides a clear representation of task efficiency, with consistent data entries for all participants. Qualitative feedback from the post-task surveys was summarized and organized separately, capturing participants’ ratings on comfort, ease of use, stroke control, and overall satisfaction. Open-ended responses were reviewed to identify key observations and trends in participants’ experiences with traditional and innovative brushes.

 ISSN 2723-6471

This comprehensive data organization prepares the study for the analysis phase, where statistical methods will be applied to derive meaningful conclusions on brush performance and user satisfaction.

3.5. Data Analysis

Following the organization of data, descriptive and inferential statistical methods were used to evaluate the performance of traditional and innovative brushes. Descriptive statistics, including mean, standard deviation, and range, were calculated for task completion times, paint usage, and user satisfaction survey scores, providing a comprehensive overview of participant interactions with each brush type. Standard deviations revealed performance variability, offering insights into the consistency of outcomes across tasks. This data comparison established a baseline understanding of relative performance differences. Inferential analysis, through t-tests and ANOVA where necessary, assessed the statistical significance of observed differences, examining whether innovative brushes demonstrated measurable improvements in task efficiency, paint usage, and user satisfaction. Qualitative data from post-task surveys underwent thematic analysis, categorizing open-ended feedback into themes such as comfort, stroke control, ease of use, and overall satisfaction. Identifying recurring themes added depth and context to the quantitative results, offering a holistic perspective on brush performance through both measurable outcomes and participant perceptions.

4. Results and Discussion

4.1. Performance Results

The study results indicate significant performance differences between traditional and innovative watercolor brushes in task completion time, paint usage, and stroke precision across Still-Life Painting, Large-Area Washes, and Detailed Line Work. Table 1 summarizes descriptive statistics for task completion times, highlighting mean, standard deviations, and ranges for each task type. Innovative brushes consistently demonstrated lower mean times and narrower ranges across tasks, indicating improved efficiency and more consistent performance compared to traditional brushes.

Table 1. Summary of Task Completion Time Statistics

Task	Brush Type	Mean (minutes)	Standard Deviation	Range
Still-Life	Traditional	15.89	0.39	1.3
	Innovative	13.88	0.33	1.1
Large-Area Wash	Traditional	9.95	0.29	0.9
	Innovative	8.52	0.25	0.8
Detailed Line Work	Traditional	13.04	0.42	1.4
	Innovative	10.79	0.33	1.1

The innovative brushes consistently achieved faster average task completion times across all tasks compared to traditional brushes. For the Still-Life Task, innovative brushes averaged 13.88 minutes, whereas traditional brushes took 15.89 minutes. In the Large-Area Wash Task, innovative brushes averaged 8.52 minutes compared to 9.95 minutes for traditional brushes. For Detailed Line Work, innovative brushes averaged 10.79 minutes, while traditional brushes required 13.04 minutes. These significant differences, confirmed by t-test results with p-values well below 0.05, indicate that the faster completion times for innovative brushes are unlikely to be due to random chance. Table 2 shows the t-test results for task completion times across all tasks.

Table 2. T-Test Results of Task Completion Time

Task	T-Statistic	P-Value
Still-Life	15.28	4.10E-15
Large-Area Wash	14.33	2.04E-14

Detailed Line Work	16.35	7.43E-16

Each row shows the t-statistic and corresponding p-value, assessing the significance of differences between traditional and innovative brushes. The extremely low p-values (all < 0.05) for each task confirm significant improvements in task efficiency with innovative brushes, supporting the hypothesis that these brushes enable faster completion times. This suggests that their superior bristle and handle quality may lead to more efficient brushstrokes and smoother application.

Paint usage, measured in grams, also differed between brush types. Table 3 presents descriptive statistics for paint usage across three painting tasks—Still-Life, Large-Area Wash, and Detailed Line Work—comparing traditional and innovative brushes. The innovative brushes consistently required less paint, with mean reductions across all tasks, suggesting enhanced paint efficiency due to improved bristle materials that better retain and distribute paint.

Table 3. Summary of Paint Usage Statistics

Task	Brush Type	Mean (grams)	Standard Deviation	Range
Still-Life	Traditional	2.97	0.1	0.3
	Innovative	2.44	0.11	0.3
Large-Area Wash	Traditional	4.58	0.12	0.4
	Innovative	3.96	0.1	0.3
Detailed Line Work	Traditional	1.57	0.07	0.2
	Innovative	1.21	0.08	0.2

On average, innovative brushes used less paint due to improved paint retention and controlled release. In the Still-Life Task, innovative brushes consumed 2.44 grams, compared to 2.97 grams for traditional brushes. For Large-Area Washes, innovative brushes required 3.96 grams, while traditional brushes used 4.58 grams. In Detailed Line Work, innovative brushes averaged 1.21 grams, compared to 1.57 grams for traditional brushes. Consistent t-test results with significant p-values (all < 0.05) support these findings. Table 4 presents the t-test results, showing t-statistics and p-values for paint usage comparisons, confirming significant paint efficiency improvements with innovative brushes.

Table 4. T-Test Results of Paint Usage

Task	T-Statistic	P-Value
Still-Life	13.72	5.91E-14
Large-Area Wash	15.41	3.33E-15
Detailed Line Work	12.93	2.49E-13

4.2. User Satisfaction Results

User feedback on comfort, ease of use, and overall satisfaction highlights the perceived benefits of the innovative brushes over traditional brushes, as collected through post-task surveys and workshop discussions. Participants provided insights into their experiences using both brush types, focusing on comfort and control during various painting tasks. User satisfaction scores reveal how the innovative brushes influenced the painting process, offering enhanced comfort and ease of use. This data is summarized in table 5, which presents the descriptive statistics for user satisfaction ratings (1-5 scale) across four key metrics: Comfort, Ease of Use, Stroke Control, and Overall Satisfaction. The innovative brushes consistently received higher mean ratings, with narrower ranges and lower standard deviations, suggesting a more consistently positive user experience. These findings indicate that the ergonomic and design improvements in the innovative brushes contribute to greater user satisfaction, enhancing both comfort and precision in artists' work.

 ISSN 2723-6471

Table 5. Summary of User Satisfaction Statistics

Metric	Brush Type	Mean (1-5)	Standard Deviation	Range
Comfort	Traditional	3.27	0.46	1
	Innovative	4.67	0.49	1
Ease of Use	Traditional	3.13	0.35	1
	Innovative	4.73	0.46	1
Stroke Control	Traditional	3.53	0.52	1
	Innovative	4.73	0.46	1
Overall Satisfaction	Traditional	3.13	0.35	1
	Innovative	4.87	0.35	1

Participants rated the innovative brushes significantly higher in comfort across all tasks, averaging 4.67 out of 5, compared to 3.27 for traditional brushes. This difference suggests that the innovative brushes, particularly the round-handled models, offered a more ergonomic grip, reducing strain and enabling prolonged use without discomfort. Many participants noted that the round handles facilitated a relaxed grip, beneficial for extended tasks like Still-Life Painting. Conversely, feedback on traditional brushes often cited fatigue and hand strain due to their less ergonomic design. Innovative brushes also received high ratings for ease of use, averaging 4.73 compared to 3.13 for traditional brushes. Participants frequently mentioned smoother, more controlled strokes with the innovative brushes, particularly in precision tasks like Detailed Line Work. Feedback from workshops highlighted that the improved bristle quality and flexibility of the innovative brushes enhanced paint application, making them versatile for both broad washes and intricate details. Participants praised the brushes' ability to retain shape under pressure, whereas traditional brushes were noted for inconsistent stroke width and less predictability. Overall satisfaction was also higher for innovative brushes, averaging 4.87 out of 5, compared to 3.13 for traditional brushes. Workshop discussions revealed that participants found the innovative brushes “intuitive” and “reliable,” meeting expectations for both casual and professional use. Durability was also highlighted, with innovative brushes maintaining their quality over multiple uses, as reflected in satisfaction ratings and positive comments. In contrast, traditional brushes were deemed adequate for basic tasks but lacking refinement for complex techniques. Table 6 summarizes the t-test results for user satisfaction metrics, showing statistically significant differences (p-values < 0.05) favoring innovative brushes across all criteria.

Table 6. T-Test Results of User Satisfaction

Metric	T-Statistic	P-Value
Comfort	-8.1	7.99E-09
Ease of Use	-10.73	1.97E-11
Stroke Control	-6.73	2.59E-07
Overall Satisfaction	-13.49	8.96E-14

4.3. Durability Findings

The durability of the brushes was assessed by examining the bristle wear and handle condition after extended use, reflecting each brush type’s ability to withstand prolonged and repeated application. Data on these durability metrics, obtained from both the original paper’s testing and post-experiment evaluations, highlight substantial differences in longevity between the traditional and innovative brushes. The results underscore the enhanced durability of the innovative brushes, which maintained their structure and performance quality over time compared to the traditional brushes. Table 7 provides the descriptive statistics for Bristle Condition and Handle Condition, comparing the

 ISSN 2723-6471

durability of traditional and innovative brushes. The table includes mean scores, standard deviations, and ranges, showing that the innovative brushes scored higher in both bristle and handle condition. This indicates that the innovative brushes maintained their quality better over time, reflecting greater durability and resilience compared to traditional brushes.

Table 7. Summary of Durability Statistics

Metric	Brush Type	Mean	Standard Deviation	Range
Bristle Condition	Traditional	3.47	0.52	2
	Innovative	4.56	0.5	1
Handle Condition	Traditional	3.56	0.56	2
	Innovative	4.49	0.5	1

The innovative brushes demonstrated significantly reduced bristle wear across all tasks, with participants rating their bristle condition at an average of 4.56 out of 5 compared to 3.47 for traditional brushes. This suggests that innovative brush bristles maintained their shape and resilience even after extended use. In tasks involving detailed line work, which demanded precise, repetitive strokes, innovative brushes exhibited minimal fraying or splitting, a common issue with traditional brushes. User feedback indicated that the advanced synthetic fibers used in the innovative brushes not only mimicked natural hair but also offered superior longevity, resisting wear and maintaining consistent paint flow and precision critical for high-quality strokes. Regarding handle durability, innovative brushes also outperformed traditional brushes, with average condition ratings of 4.49 compared to 3.56. Participants highlighted that innovative brush handles felt sturdier and provided comfortable grips during long sessions. Specifically, the round-handled designs were praised for their ergonomic features, enhancing user comfort and resisting wear. Conversely, traditional brushes frequently displayed signs of wear such as peeling paint and loose handle materials after intensive use, like large-area washes. Testing observations from the original study attribute the durability of innovative handles to their reinforced wooden cores and protective finishes, which minimize wear. Table 8 details the t-test results for bristle and handle conditions, with t-statistics and p-values confirming the statistically significant differences (p-values < 0.05) in durability, underscoring the superiority of innovative brushes over traditional ones.

Table 8. T-Test Results of Durability

Metric	T-Statistic	P-Value
Bristle Condition	-14.27	2.65E-31
Handle Condition	-11.73	6.58E-24

4.4. Hypothesis Testing

The primary goal of this research was to assess whether the innovative brushes offered measurable improvements over traditional brushes in terms of task efficiency, user satisfaction, and durability. The following hypotheses were tested to determine if the innovative brushes demonstrated statistically significant advantages across these three areas.

H1: Task Efficiency Improvement

Hypothesis 1 (H1) proposed that the innovative brushes enhance task efficiency by reducing completion times for specific tasks. T-tests were conducted on task completion times for Still-Life Painting, Large-Area Washes, and Detailed Line Work, revealing that the innovative brushes significantly decreased task times compared to traditional brushes, with mean times consistently lower and p-values well below the 0.05 significance threshold.

H2: Increased User Satisfaction

Hypothesis 2 (H2) asserted that artists would exhibit greater satisfaction with the innovative brushes. User satisfaction surveys rated both brush types on comfort, ease of use, and overall satisfaction, with results showing significantly

 ISSN 2723-6471

higher average scores for innovative brushes. T-tests yielded p-values below 0.05, indicating the statistical significance of these differences. Artists highlighted enhanced comfort, better control, and overall enjoyment when using the innovative brushes.

H3: Enhanced Durability

Hypothesis 3 (H3) examined the durability of the innovative brushes compared to traditional brushes, focusing on bristle wear and handle condition. Descriptive statistics showed better condition ratings for innovative brushes, with t-tests confirming statistically significant differences (p-values below 0.05). The innovative brushes demonstrated superior durability, maintaining their bristle shape and handle integrity after extended use.

4.5. Discussion

The findings of this study demonstrate that innovative watercolor brushes significantly outperform traditional brushes in terms of task efficiency, user satisfaction, and durability. Quantitative data from task completion times, paint usage, and durability assessments align with and build on the qualitative feedback from artists during workshops and surveys. Reduced task times with the innovative brushes indicate better ergonomics and more controlled brushstrokes, allowing seamless transitions between different techniques like broad washes and fine lines. The advanced bristle materials of the innovative brushes offer improved paint retention and release, facilitating a consistent pigment flow and enhancing precision. Artists' positive feedback on smoother, more controlled movements with the innovative brushes underscores the success of the ergonomic and material improvements.

User satisfaction was consistently higher with the innovative brushes, particularly regarding comfort and ease of use. Round-handled brushes reduced hand fatigue, offering a natural grip, while flat-handled brushes provided stability for tasks requiring continuous pressure. The superior durability of the innovative brushes, evidenced by their ability to maintain bristle and handle quality over extended use, further highlights their suitability for professional applications. Traditional brushes, in contrast, showed signs of wear. These findings emphasize the importance of ergonomic design and advanced materials in brush performance, suggesting that future designs should continue to prioritize user comfort, effective grip shapes, and durable materials to enhance overall user experience.

5. Conclusion

This study demonstrates that innovative brushes significantly outperform traditional brushes in terms of task efficiency, user satisfaction, and durability. Quantitative analyses confirmed that the innovative brushes consistently reduced task completion times, minimized paint usage, and maintained better bristle and handle conditions over extended use. These results align with qualitative feedback from artists, who praised the brushes for their smooth application, comfort, and durability. The statistical significance of these differences supports the hypothesis that innovative brushes offer a more efficient, satisfying, and durable tool for watercolor artists. These findings have practical implications for brush design, emphasizing the value of ergonomic handles and advanced bristle materials to enhance user comfort and performance. Brush manufacturers are encouraged to explore varied handle designs and synthetic bristle technologies that mimic natural hair's qualities while offering greater durability. Although this study provides valuable insights, limitations include the subjective nature of user satisfaction ratings and a relatively small sample size. Future research could expand to larger, more diverse artist samples, explore different painting mediums, and integrate digital tools for precise performance evaluation.

6. Declarations

6.1. Author Contributions

Conceptualization: S.C.; Methodology: S.C.; Software: S.C.; Validation: S.C.; Formal Analysis: S.C.; Investigation: S.C.; Resources: S.C.; Data Curation: S.C.; Writing Original Draft Preparation: S.C.; Writing Review and Editing: S.C.; Visualization: S.C.; The author has read and agreed to the published version of the manuscript.

6.2. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

6.3. Funding

This research was supported by the Science, Research and Innovation Promotion Fund, Thailand Science Research and Innovation (TSRI), through Rajamangala University of Technology Thanyaburi (FRB66E0802) (Grant No.: FRB660012/0168).

6.4. Institutional Review Board Statement

Not applicable.

6.5. Informed Consent Statement

Not applicable.

6.6. Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] S. Yu and L. Wang, "Watercolor Painting Under the Background of Industrial and Commercial Development in the Late Qing Dynasty," *Front. Humanit. Soc. Sci.*, vol. 3, no. 6, pp. 8–11, 2023, doi: 10.54691/fhss.v3i6.5136.

[2] H. Wang, "A location-sentiment-aware recommender system for both home-town and out-of-town users," *Proc. ACM SIGKDD Int. Conf. Knowl. Discov. Data Min.*, vol. 2017, no. 1, pp. 1135–1143, 2017, doi: 10.1145/3097983.3098122.

[3] Z. Chen, "The Study of Negative Pragmatic Transfer and Its Pedagogic Implications," Proceedings of the 2022 4th International Conference on Literature, Art and Human Development (ICLAHD 2022), vol. 2023, no. Feb., pp. 1109–1117, 2023, doi: 10.2991/978-2-494069-97-8_141.

[4] J. Gao, "Integration and Exploration of Digital Painting and Traditional Watercolor Painting," *Arts Stud. Crit.*, vol. 4, no. 1, pp. 7-9, 2023, doi: 10.32629/asc.v4i1.1268

[5] Q. Wang and H. Alamusi., "Design of Watercolor Cultural and Creative Products Based on Style Transfer Algorithm," *Math. Probl. Eng.*, vol. 2022, no. 1, pp. 1–9, 2022, doi: 10.1155/2022/2711861.

[6] A. Panotopoulou, S. Paris, and E. Whiting, "Watercolor Woodblock Printing With Image Analysis," *Comput. Graph. Forum*, vol. 37, no. 2, pp. 275–286, 2018, doi: 10.1111/cgf.13360.

[7] X. Song, "Teaching Design of Chinese Contemporary Stylized Watercolor Based on Quadratic Exponential Smoothing Model," *Appl. Math. Nonlinear Sci.*, vol. 9, no. 1, pp. 1-14, 2023, doi: 10.2478/amns.2023.2.00750.

[8] Y. Hara, T. Sanada, A. Fukunaga, and H. Hiyama, "Effect of Viscoelasticity of PVA Brush on Friction During Post-CMP Cleaning: A Guideline for Nodule Configuration," *Solid State Phenom.*, vol. 219, no. 1, pp. 148–152, 2014, doi: 10.4028/www.scientific.net/ssp.219.148.

[9] S. Kalasin and M. M. Santore, "Near-Surface Motion and Dynamic Adhesion During Silica Microparticle Capture on a Polymer (Solvated PEG) Brush via Hydrogen Bonding," *Macromolecules*, vol. 49, no. 1, pp. 334–343, 2015, doi: 10.1021/acs.macromol.5b01977.

[10] R. K. Singh, C. Patel, D. Trio, E. McNamara, and C. Wargo, "PVA Brush Technology for Next Generation Post-CMP Cleaning Applications," *Ecs Trans.*, vol. 33, no. 10, pp. 167–173, 2010, doi: 10.1149/1.3489057.

[11] S. Gon, K.-N. Kumar, K. Nüsslein, and M. M. Santore, "How Bacteria Adhere to Brushy PEG Surfaces: Clinging to Flaws and Compressing the Brush," *Macromolecules*, vol. 45, no. 20, pp. 8373–8381, 2012, doi: 10.1021/ma300981r.

[12] H. Li, "MSGD: A Novel Matrix Factorization Approach for Large-Scale Collaborative Filtering Recommender Systems on GPUs," *IEEE Trans. Parallel Distrib. Syst.*, vol. 29, no. 7, pp. 1530–1544, 2018, doi: 10.1109/TPDS.2017.2718515.

[13] F. Lin, K. Muzumdar, N. Laptev, M.-V. Curelea, S. Lee, and S. Sankar, "Fast Dimensional Analysis for Root Cause Investigation in a Large-Scale Service Environment," *Proc. Acm Meas. Anal. Comput. Syst.*, vol. 4, no. 2, pp. 1–23, 2020, doi: 10.1145/3392149.

[14] A. V. Veelen, R. Goossens, J. J. Jakimowicz, C. J. Snijders, J. J. Jacobs, and D. W. Meije, "New Ergonomic Guidelines for Laparoscopic Instruments," *Minim. Invasive Ther. Allied Technol.*, vol. 10, no. 3, pp. 163–167, 2001, doi: 10.1080/136457001753192286.

 ISSN 2723-6471

[15] L. F. M. Kuijt-Evers, T. Bösch, M. A. Huysmans, M. P. d. Looze, and P. Vink, "Association Between Objective and Subjective Measurements of Comfort and Discomfort in Hand Tools," *Appl. Ergon.*, vol. 38, no. 5, pp. 643–654, 2007, doi: 10.1016/j.apergo.2006.05.004.

[16] M. F. Hamizatun, "Ergonomic Embedded in Designing Welding Assembly Tool for Automotive Manufacturing Process," *J. Mod. Manuf. Syst. Technol.*, vol. 7, no. 2, pp. 23–30, 2023, doi: 10.15282/jmmst.v7i2.9923.

[17] R. M. C. Herrera, M. A. T. Blanco, J. C. C. Carabeo, F. D. B. Ramilo, J. R. D. D. Silva, N. O. M. Nuqui, M. T. Espino, B. J. Tuazon, and J. R. C. Dizon, "3d-Printed Ergonomic Tool Handles," *Adv. Sustain. Sci. Eng. Technol.*, vol. 4, no. 2, pp. 1-10, 2022, doi: 10.26877/asset.v4i2.13025.

[18] C. Wang and D. Cai, "Hand Tool Handle Design Based on Hand Measurements," *Matec Web Conf.*, vol. 119, pp. 1-5, 2017, doi: 10.1051/matecconf/201711901044.

[19] N. J. Seo and T. J. Armstrong, "Effect of Elliptic Handle Shape on Grasping Strategies, Grip Force Distribution, and Twisting Ability," *Ergonomics*, vol. 54, no. 10, pp. 961–970, 2011, doi: 10.1080/00140139.2011.606923.

[20] A. O. Pugachev and P. N. v. d. Helm, "Calibration of Porous Medium Models for Brush Seals," *Proc. Inst. Mech. Eng. Part J. Power Energy*, vol. 223, no. 1, pp. 83–91, 2008, doi: 10.1243/09576509jpe641.

[21] B. Qiu, J. Li, and X. Yan, "Investigation Into the Flow Behavior of Multi-Stage Brush Seals," *Proc. Inst. Mech. Eng. Part J. Power Energy*, vol. 228, no. 4, pp. 416–428, 2014, doi: 10.1177/0957650914522456.

[22] A. Haug, "Psychologically Durable Design – Definitions and Approaches," *Des. J.*, vol. 22, no. 2, pp. 143–167, 2019, doi: 10.1080/14606925.2019.1569316.