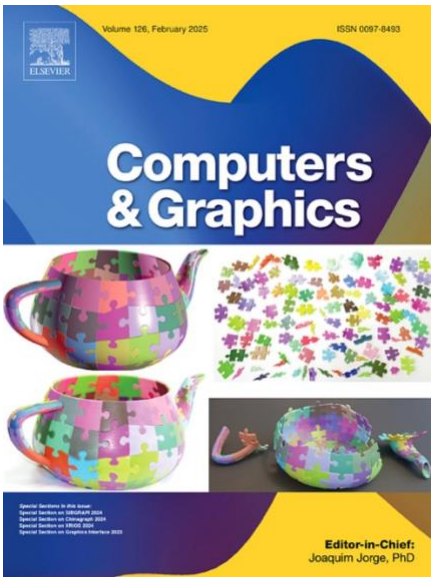
The Citation Impact of Reproducible Research: A Case Study in Computers & Graphics



ReproResearch Analytics

Project Report

41004 AI/Analytics Capstone Project

Md Rakib Hasan (14480545)
Jun Hyun Lim (25175391)
Denise Zamora (14441517)
Zhihong Yu (12996373)

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1. Executive Summary

This project was conducted for ***Computers & Graphics***, a well-known peer-reviewed journal, to investigate whether research papers certified as reproducible receive more citations than their non-reproducible counterparts in the *Computers & Graphics* journal. Reproducibility has become vital to the integrity of scientific publications, especially in computational domains; the journal's association with the ***Graphics Replicability Stamp Initiative (GRSI)*** demonstrates its commitment to upholding this standard. Although the certification encourages reproducibility, it remains undetermined whether this certification leads to measurable academic outcomes, such as elevated citation counts or increased research visibility.

To answer this, our team first collected and merged citation data from ***Google Scholar*** with reproducibility metadata from the ***GRSI*** to create a structured dataset for analysis. Throughout the whole investigation we used data exploration, applied different statistical modelling and hypothesis testing—including Ordinary Least Squares regression, non-parametric testing—to evaluate the relationship between reproducibility and citation performance, while controlling for confounding factors such as publication year and journal rank.

Key Findings:

- Reproducibility certification, while valuable, was **not a statistically significant predictor** of higher citation counts as there is **no statistically significant difference in mean or median citation counts** between certified reproducible and non-certified papers.
- While reproducibility certification doesn't translate into higher citation counts on average, but it does **correlate with a lower chance of being uncited**. On average **certified reproducible papers are ~60% less likely to get zero citation** than their counterparts.
- **Adoption of the GRSI** / replicability certification is **steadily increasing**. From **4.26%** in 2016, the rate has risen to **near 13%** in 2024. Currently the average annual adaptation rate is **14.7%.**
- After **Year 2020**, in Computer and Graphics Journal **total published papers were increased** yet **total citations were significantly decreased**. Despite this, the **median annual citation rate** for post-2020 papers remains **16.5% higher** than that of **pre-2020 publications**, suggesting that citations for recent papers will continue to grow. Conversely, the steep drop in total citations during 2024 and 2025 indicates that, as the journal accepted a greater volume of submissions, a larger share of lower-impact papers was introduced.

- **Citation growth** has shown **association with publication's topic** than replicability certification.
- After 2021, papers related to ***Deep Learning & 3D Computer Vision*** saw the biggest gain in citations, indicating a strong community pivot toward deep learning approaches in vision and 3D data. ***3D Modelling & Surface Reconstruction*** saw the largest drop in citation gain, suggesting fewer papers in this traditional area post-2020.
- ***3D Modelling & Surface Reconstruction*** accounts for 40% of all replicable papers published after 2021. Even though this area declined overall, it remains the centrepiece of certified reproducible papers.
- ***Deep Learning for 3D Computer Vision*** is the next most-common among certified papers (~26%), showing that certified replicable papers have kept pace with the community's shift toward deep-learning approaches.

Key Recommendations:

- It is recommended that the journal continue to prominently **endorse and label GRSI-certified papers emphasizing that certified reproducible papers are approximately 60% less likely to receive low citations**, thereby reinforcing the clear benefit to submitting authors.
- It is recommended to **closely track both submission volume and citation metrics together**. Since 2020, total publications have risen while overall citation counts have dropped significantly; yet the median annual citation rate for post-2020 papers remains approximately 16.5% higher than earlier papers—revealing some growth potential.
- It is recommended to **regulate total publications acceptance volume** as regulating published papers quality and quantity can mitigate the issue of sudden recent drop in citations and growing influx of lower-impact publications.
- It is recommended to **focus on high-quality papers in areas with growing interest**—like deep learning for 3D computer vision
- It is recommended to **develop BI (business intelligence) dashboard** to monitor **citation trends, reproducibility adoption areas, area-based citation performance and growing topic in academic community.**

This report presents evidence-based answers to the journal's business questions and highlights actionable strategies for integrating data-driven decision-making into future publishing practices.

2. Business Problem

As reproducibility is a key concern in scientific publishing, specifically in computational disciplines where code, data, and methods must be transparent and verifiable, Our Client **Computers & Graphics** is seeking evidence-based insights to guide its editorial and publishing strategy. Although transparency is essential in research, it remains unclear whether reproducibility certification drives higher number of citations. Accordingly, our central business question is "**Do research papers certified as reproducible receive more citations than their non-reproducible counterparts in the Computers & Graphics journal?**"

To address this gap, we adopted a fully data-driven approach—beginning with comprehensive data collection followed by rigorous cleaning, normalization, and integration. We then performed exploratory analyses and imposed statistical controls to account for external biases, using hypothesis testing and regression modelling to isolate the effect of reproducibility certification on citation impact. The insights uncovered are presented in this report with clear, empirical evidence.

3. Data Exploration

To address the business question, we first examined several aspects of the dataset. There are three datasets used in this project—**citations.csv**, **reproducibility.csv, Final_Dataset.csv.** The first two datasets are the raw data after data collection and then later processed and unified into a final structured dataset.

3.1 Dataset & Attributes Overview

The first dataset, **"citations.csv"**, contains detailed metadata and citation metrics for 1,400 academic articles. Each entry includes information such as the **article's title, authors, publication year, publisher, and citation-related figures like total citations, citations per year, and per author**. It also includes **links to the article, full-text sources, and abstracts** where available. However, **some columns contain little to no data**—such as ISSN, StartPage, EndPage, Volume, Issues etc. Additionally, some of the columns such QueryDate, Type etc may be rendered as unnecessary as this may have little connection for the analysis. This dataset also exhibited a minor encoding issue which was hindering the data reading in python. Later it was fixed by converting the dataset into a its proper encode before loading the data in analytic tools.

The **“reproducibility.csv”** dataset is more focused and concise, listing just **88 entries with three core fields: the article’s DOI, title, and a direct URL**. This dataset contains information of articles specifically related to reproducibility which were certified by the GSRI (Graphics Stamp Research Initiative). The final structured dataset consists of **1,185 journal articles from the journal Computers & Graphics**, with important and relevant variables for this project such as citation count, publication year, number of authors, journal rank (GSRank), and reproducibility status. Refer to section *10. Appendix* for the description of each attribute in our merged dataset.

3.2 Data Preprocessing

Following the merging of the initial datasets—**detailed in the Data Modelling section—** the resulting data was organized and formatted to ensure analytical integrity. To achieve this, we:

- **Removed duplicate and invalid records.**
- **Dropped columns that were missing data or deemed irrelevant.**
- **Filtered citation-count outliers using the interquartile range (IQR) method.**
- **Created a binary "Reproducible" field, coding certified papers as 1 and non-certified papers as 0.**

Finally, we achieved a structured dataset named “Final_Dataset.csv”, which was ready to use for our analysis.

3.2 Initial Data exploration

Initial data exploration showed that only 7.4% of papers in the dataset are certified as reproducible, while the remaining 92.6% are non-certified. The following pie chart illustrates the proportion of the two groups in the dataset.

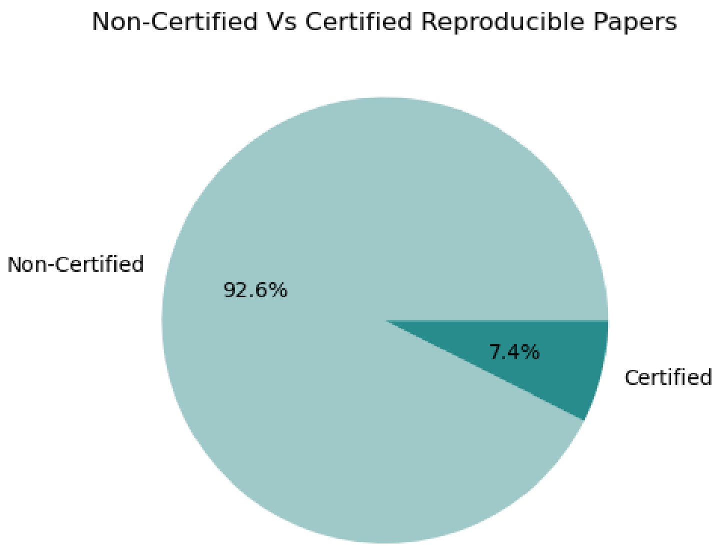

Figure 1: Certified Vs Non-Certified Reproducible Papers

This demonstrates that the data is highly skewed. We also examined the citation distribution in the dataset and found that it is not normally distributed. The following graph clearly illustrates the skewness in the citation distribution.

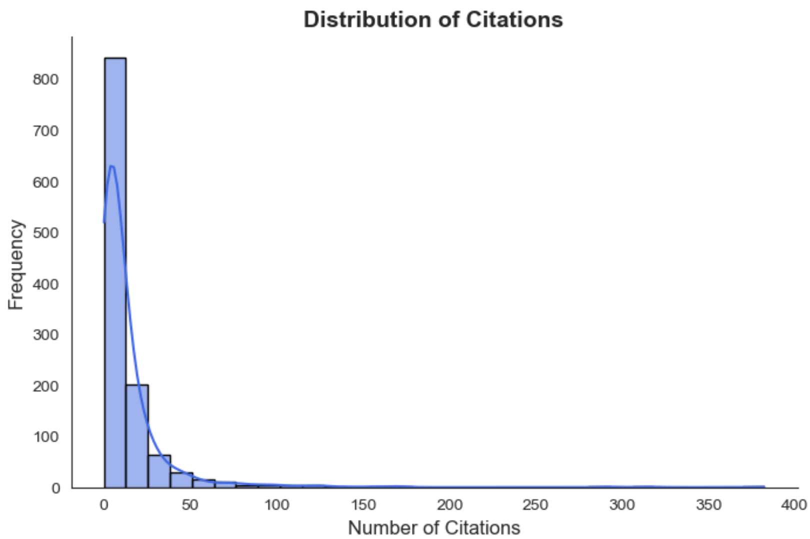

Figure 2: Citation Distribution

We conducted a Shapiro–Wilk test to confirm this, and the results (W=0.4501, p=5.854e-51 < 0.05) indicate that the data are not normally distributed.

4. Modelling

4.1 Data Modelling

Firstly, in one of the datasets, "**reproducible.csv**," we had **information about all the papers that are certified as reproducible**, but it had **no information about the citations of those papers**. On the other hand, the other dataset – "**citations.csv**" – **does not contain any information about the reproducibility of those papers**. However, since our analysis required both types of information to be considered together, we decided to merge the datasets. To proceed with the merging process, we need a merging point or joining condition. As we are working with academic papers, **the unique characteristic of these papers that can separate each other uniquely is the Digital Object Identifier, known as DOI number/address**. When we explored the data, we saw that the **DOIs for all the papers in reproducible.csv dataset were present but in the citations.csv dataset were all empty**. In the figures below it shows the missing Doi information in the citations dataset.

G	H	I	J	K	L	S	T	U	V
ArticleURL	CitesURL	GSRank	QueryDate	Type	DOI	ECC	CitesPerYear	CitesPerAuth	AuthorC
https://www.s	https://schola	4	16/2/2025 20:07	HTML		322	35.78	81	
https://www.s	https://schola	6	16/2/2025 20:07			169	18.78	34	
https://www.s	https://schola	14	16/2/2025 20:07			112	12.44	28	
https://www.s	https://schola	20	16/2/2025 20:07	HTML		108	12	18	
https://www.s	https://schola	40	16/2/2025 20:07			58	6.44	12	
https://www.s	https://schola	51	16/2/2025 20:07			37	4.11	12	
https://www.s	https://schola	60	16/2/2025 20:07			45	5	9	
https://www.s	https://schola	61	16/2/2025 20:07			55	6.11	11	
https://www.s	https://schola	69	16/2/2025 20:07			41	4.56	10	
https://www.s	https://schola	71	16/2/2025 20:07			47	5.22	12	
https://www.s	https://schola	91	16/2/2025 20:07			60	6.67	15	
https://www.s	https://schola	100	16/2/2025 20:07			23	2.56	5	
https://www.s	https://schola	101	16/2/2025 20:07			34	3.78	7	

Figure 1: Missing Doi in citation.csv dataset

This arose the scope of finding the Doi for all the papers in citations.csv dataset. In order to get the Doi information about those papers, we decided to web-scrap using python. For web-scraping, we used multiple sources to obtain DOI information. The sources we used are Semantic Scholar, CrossRef and Open Alex APIs. In the figures below shows a code snippet of web-scraping process.

The results were promising - out of 1300 papers, we successfully retrieved information for over 1200 papers. After that, we were able to merge the datasets based on Doi column in both datasets. This merging resulted in matching 80 papers of reproducibility dataset with 80 papers of citations dataset. The other 8 papers were then processed properly in the merged dataset.

4.2 Analysis Modelling & Data Mining

To address the central business problem—*whether reproducibility certification correlates with increased academic impact*—we largely used common statistical observations and hypothesis testings, at the same time we also framed the data mining problem as a combination of **predictive modelling** and **association analysis**, focusing on the citation count as the primary dependent variable. The modelling aimed to quantify the influence of reproducibility certification on citation performance while controlling for confounding variables such as publication year, topic area, and author count.

After data modelling, we conducted analysis modelling across **five analytical domains**:

- **Certification Impact on Citations and Visibility**
  We employed **Ordinary Least Squares (OLS) regression** to estimate the marginal effect of reproducibility certification on citation counts, adjusting for time and journal rank. To assess the robustness of the findings, we also applied **non-parametric testing** (Mann-Whitney U) due to citation data skewness. Additionally, **logistic regression** was used to model the binary outcomes of being uncited and ranking in the top 10% most-cited papers, uncovering that while certification does not significantly increase average citations, it reduces the probability of zero-citation papers by approximately 60%.

- **Temporal Trends**
  To analyze time-based patterns, we segmented the dataset into **pre-COVID, COVID, and post-COVID** eras. We modeled certification adoption as a **time series**, calculating the average annual adoption rate (14.7%) and identifying peaks in certification activity. This temporal modelling helped uncover systemic shifts in publication and citation behavior over time.

- **Author Analysis**
  We incorporated journal rank (GSRank) and author count into multivariate models to examine interactions between author prestige and certification status. Authors associated with higher-ranked papers were more likely to publish certified reproducible work, though this did not consistently lead to higher citation returns.

- **Topic Modelling and Citation Clusters**
  Using domain expertise and citation clustering, we defined six thematic research areas within the journal (e.g., Deep Learning for 3D Vision, Surface Reconstruction). We applied **categorical association analysis** to map certified papers to topics and analyzed how topic shifts post-2021 influenced citation patterns. This helped us

discover that while some traditional areas declined in visibility, certified papers in emerging fields kept pace with community trends.

- **Strategic Insights Modelling**
  We synthesized the outputs of all modelling efforts to provide actionable intelligence for journal editors. By comparing the probability distributions, effect sizes, and regression outputs, we translated statistical findings into **strategic publishing recommendations** aligned with the journal's long-term goals.

Bootstrap Resampling Statistical Test:

To further strengthen the reliability of our statistical inferences—especially given that the citation data was heavily skewed and not normally distributed—we employed bootstrap resampling tests as part of our analysis. This non-parametric technique involved repeatedly drawing random samples (n=33) from both certified and non-certified groups, conducting 1,000 iterations for each comparison. For each iteration, we calculated the metric of interest, and then averaged these results to obtain a robust estimate of group differences. The bootstrap approach proved particularly valuable in our context, as it does not rely on the assumption of normality and is highly effective with skewed distributions like ours. By leveraging bootstrapping, we ensured that our comparative findings—such as differences in citation rates—remained valid and unbiased, even in the presence of non-standard data distributions.

Modelling Reason & Justification:

While citation behaviour is influenced by many external factors, the modelling provided valuable insights aligned with the business objective. Regression analysis helped isolate the marginal effect of reproducibility certification while controlling for publication year and journal rank. Statistical observations further revealed that certified papers had a notably lower likelihood of being uncited. Hypothesis testing was effective in identifying the effect size or significance of patterns and relationships within the dataset. As such, the modelling served its purpose: delivering evidence-backed conclusions on certification impact, highlighting thematic trends, and supporting actionable recommendations for strategic editorial planning.

5. Findings

This section synthesizes the core insights derived from our statistical analysis and data exploration to directly address the business question. The results have been presented thematically to highlight both expected and unexpected outcomes of the analysis.

5.1 Certification Impact on Citations

Our central hypothesis—that reproducibility certification results in higher citation counts—was not supported by statistically significant evidence. Both mean and median citation counts were comparable between certified and non-certified papers.

5.1.1 Mean Citation Comparison

No statistically significant difference was observed between the average citations of certified and non-certified papers ($p > 0.05$, via Mann-Whitney U test).

From the following graph (figure 3) we can see that Mean and Medians for both certified and non-certified group are close; distributions overlap substantially. This is further confirmed by Mann–Whitney U test and Cohen's D effect size as the result shows not very ignificant difference in citation distributions.

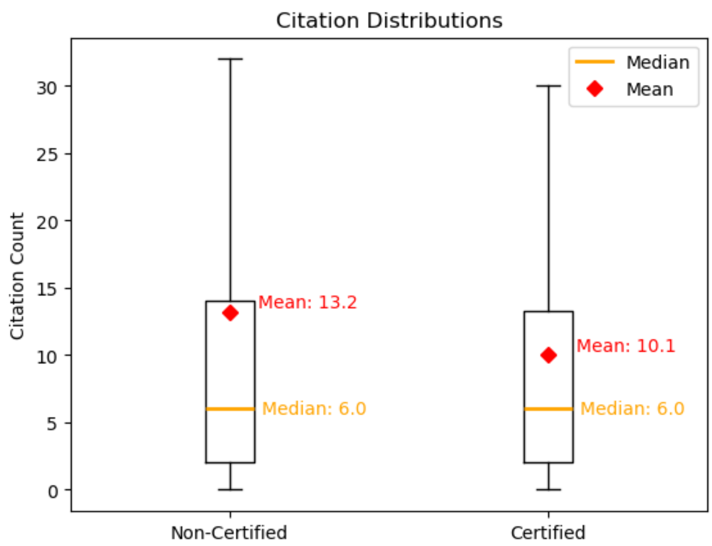

Figure 3: Boxplot Distribution of Citations

5.1.2 Regression Analysis

In multiple OLS regression test coefficient for Reproducibility variable is 0.08 and p=0.9752, which indicates reproducibility status is not a significant predictor of citations when controlling for publications' age and author count.

These statistical observations suggest that reproducibility certification alone does not lead to a measurable increase in citations across the full distribution of papers.

5.2 Certification Impact on Visibility

Despite the absence of a strong effect on citation averages, reproducibility certification was associated with **lower risk of total citation failure**:

5.2.1 Uncited Rate Reduction & Performance in the top 10%

Certified reproducible papers were ~60% less likely to receive zero citations compared to non-certified papers. Figures 4 shows the proportion of papers with zero citations (certified: 4.7% vs non-certified: 11.54%) across both certified and non-certified groups.

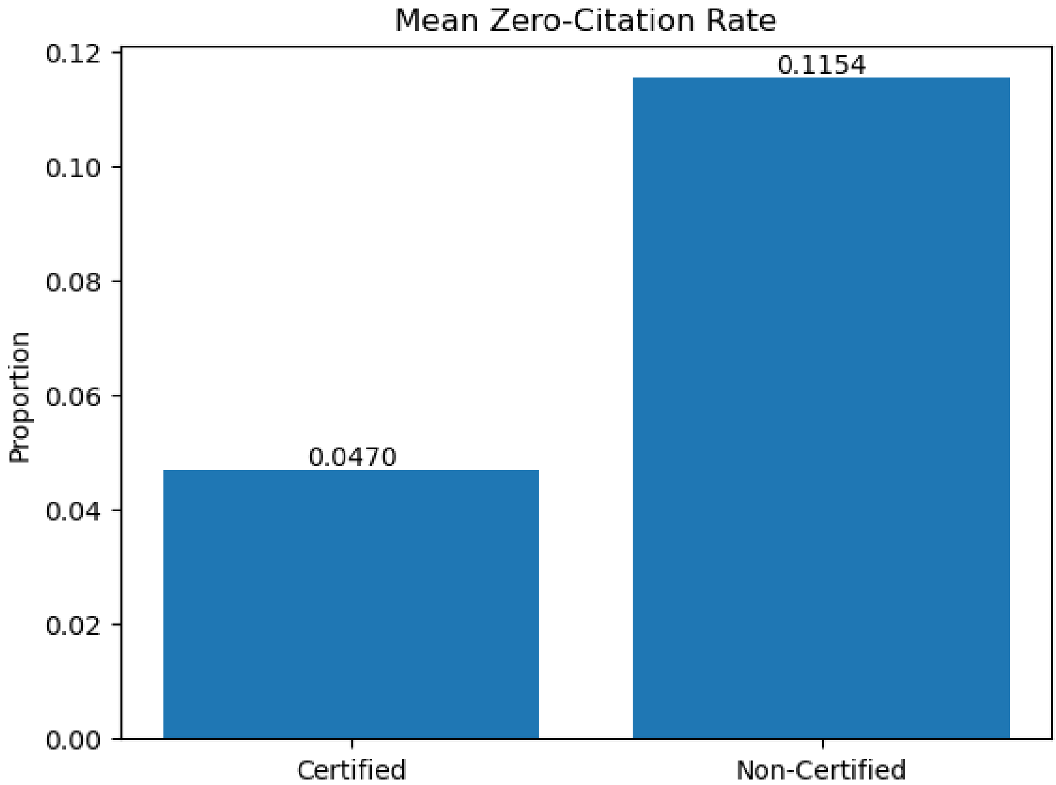

Figure 4: Average Rate of Zero-Citation Papers Across Certified and Non-Certified Groups.

5.2.2 Top 10% cited papers

Figure 5 illustrates the proportion of papers in the top ten percentiles for both groups (certified: 6.9% vs. non-certified: 10.4%). Therefore, it can be said that non-certified papers are more likely to be among the top 10% of highly cited papers, suggesting that certification does not necessarily correlate with higher citation performance at the upper end.

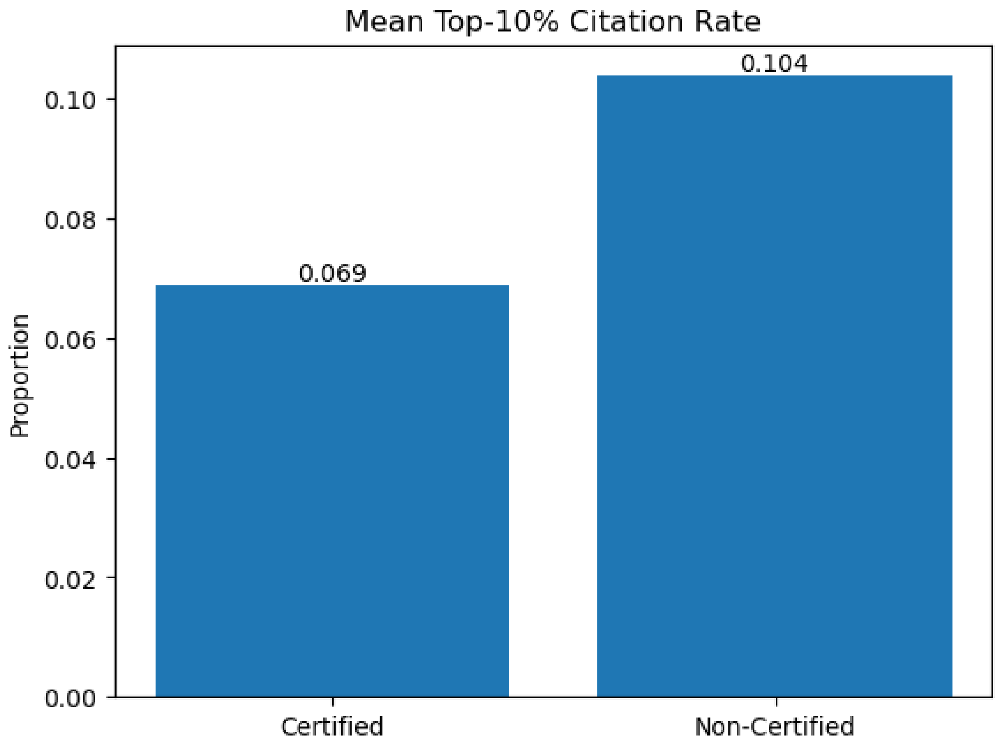

Figure 5: Average Rate of Top 10% Citation-Performing Papers in Certified vs. Non-Certified Groups

5.2.3 Early Citation Uptake

To assess whether reproducibility certification accelerates a paper's initial citation momentum or early visibility, the average annual citation rates of certified and non-certified papers were compared using a robust bootstrap resampling approach. Given the skewed nature of citation data, 10000 iterations of random sampling (n=33 from each group) were conducted, and the mean annual citation rate for each group was calculated in each iteration. Figure 6 below illustrates the average annual citation rate for certified and non-certified papers, as determined by bootstrap sampling.

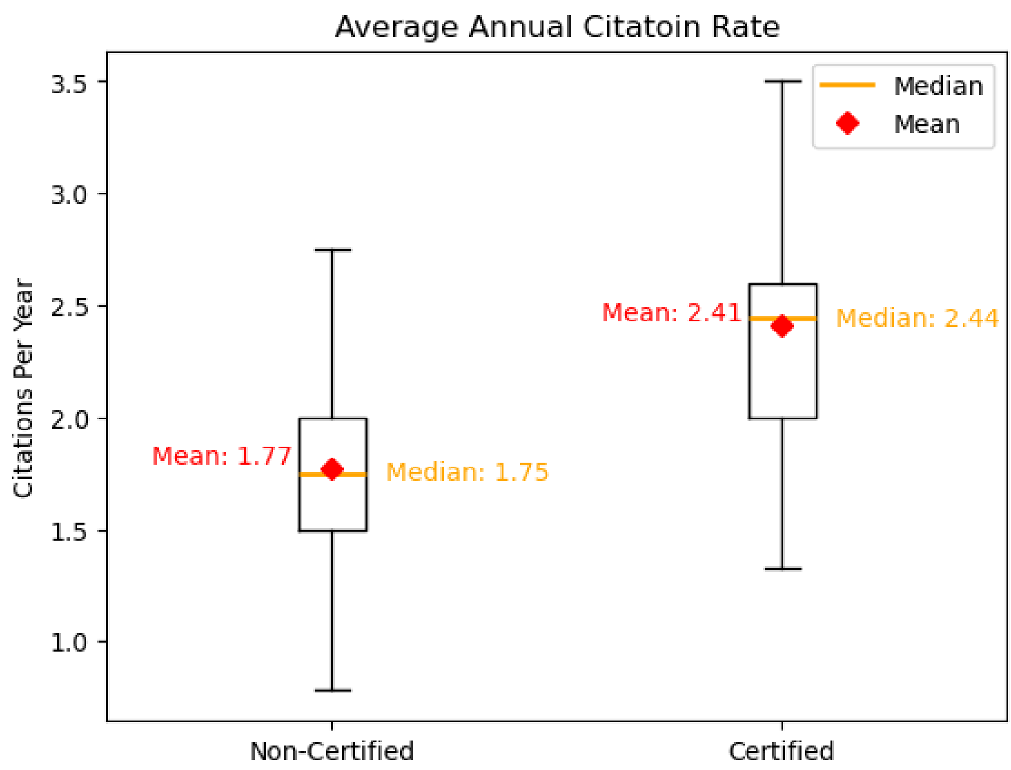

Figure 6: Distribution of Average Annual Citation Rates by Certification Status

Across bootstrap samples, certified papers consistently demonstrated a noticeable advantage in annual citation uptake. Although certification does not guarantee higher total citation counts over the paper's entire lifetime, the findings suggest that reproducible papers receive more attention per year, especially soon after publication as most of the certified papers are younger than the most non-certified papers.

Certified reproducible papers exhibit a higher average annual citation rate compared to non-certified papers. While the difference in average annual citation rates Favors certified papers, the magnitude of the effect is modest, and statistical tests indicate only a weak significance level. This means that the advantage exists, but it should be interpreted as a trend rather than a robust effect.

These observations highlight a visibility advantage—Certification may not elevate a paper to the most-cited ranks, but it clearly helps reduce the risk of receiving no citations at all.

5.3 Temporal Trends: Shifts in Publication and Citation Dynamics Post-2020

The pandemic period (year 2019-2021) marked a significant shift in publication patterns and citation dynamics:

5.3.1 Increased volume of publications and sharp drop in Citations

Post-2020 publications saw a marked increase in total publications per year yet a sharp drop in total citations (especially in 2024 and 2025) suggests saturation or an influx of lower-impact submissions.

Figure 6 illustrates the trends in paper volume and citation growth over time. Additionally, Figure 7 shows that after 2021 (the post-COVID period), the median number of **citations per paper** dropped **significantly to 4**, whereas **papers published earlier had a median of over 10**.

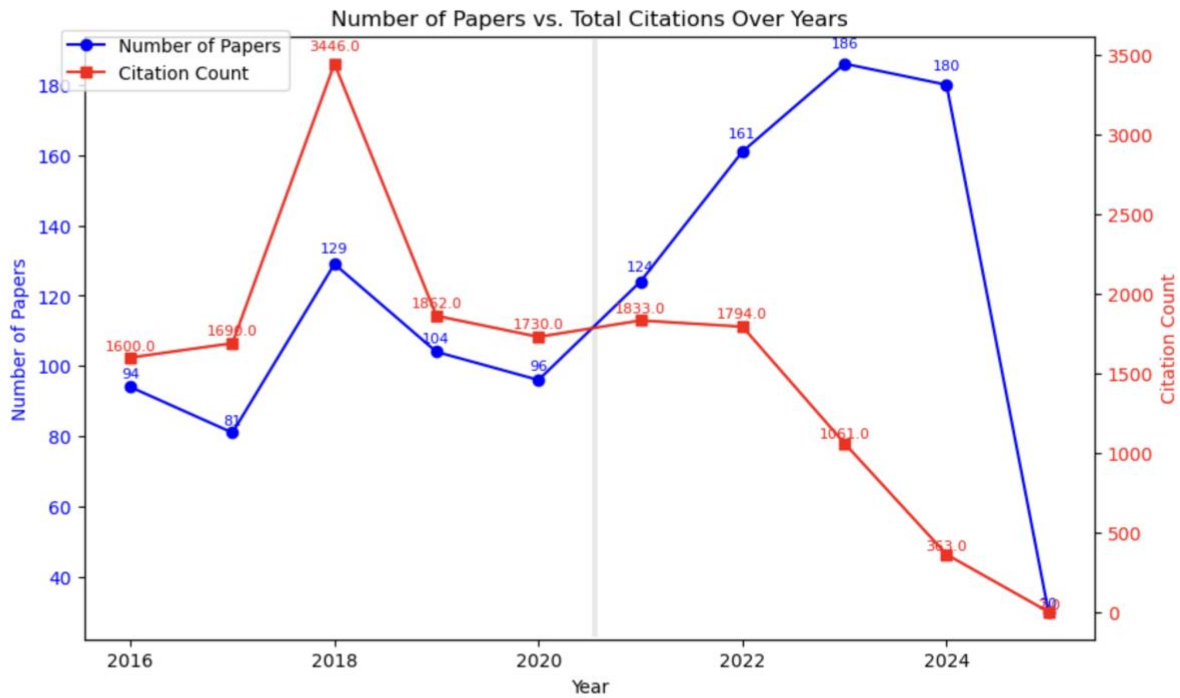

Figure 6: Number of Papers Vs Total Citations Over Years

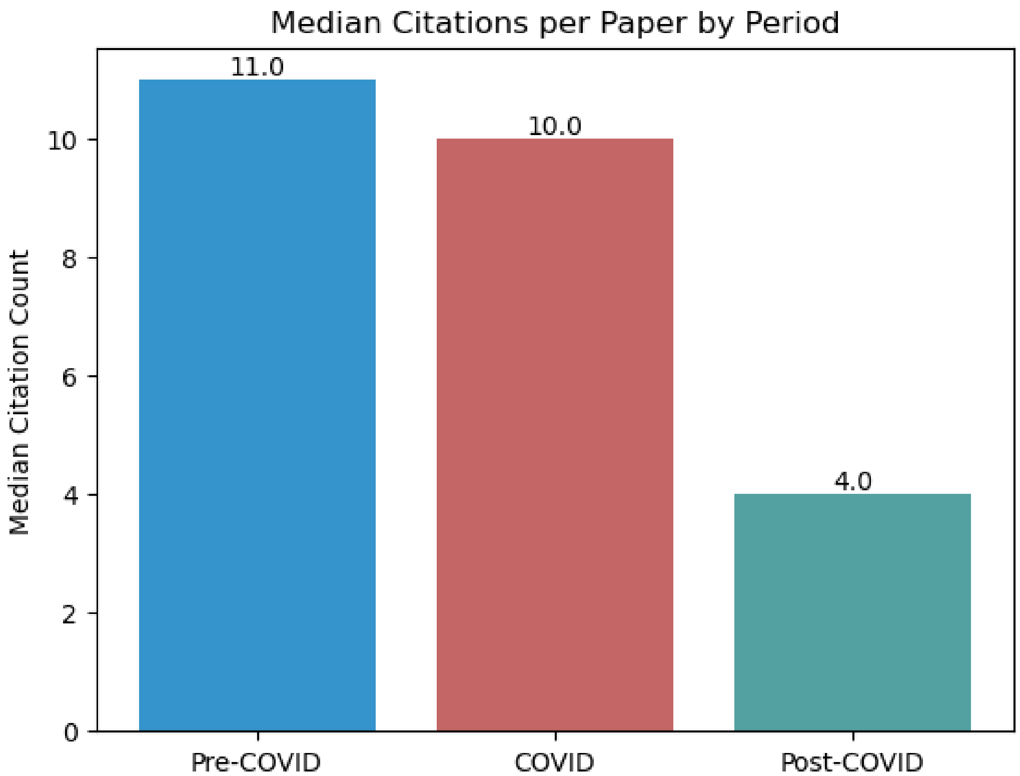

Figure 7: Median Citations per paper by period

5.3.2 Median Citation Growth:

Interestingly, the median annual citation rate for papers published after 2020 is 16.5% higher than that of pre-2020 publications—indicating stronger average performance despite a lower total citation count.

As shown in the table below, although the current median citations per paper are lower (4) compared to earlier papers (over 10), the annual citation rate remains higher than that of pre-COVID publications. **This suggests that papers published after 2020 have strong potential for future citation growth.**

Table 1: Annual Citation Rate Across Different Periods

Period	# Papers	Median Total Citations	Median Citations per Year
Pre-COVID	408	11	1.67
During-COVID	220	10	2.00
Post-COVID	557	4	2.00

This divergence between total and median citation rates indicates the importance of controlling for paper quality and impact when interpreting trends.

5.4 Temporal Trends: Certification Trends Over Time

The following graph (figure 8) illustrates the replicability adaptation trends over time. This temporal analysis revealed a steady growth in reproducibility certification:

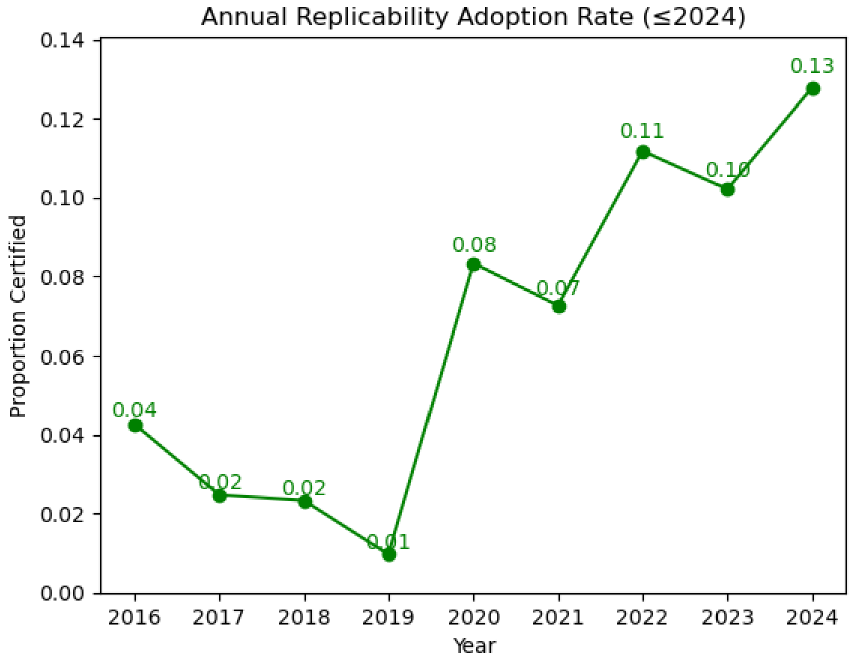

Figure 8: Annual Replicability Certificate Adaptation Rate

- **Adoption Trajectory**: Certification adoption rose from **4.26% in 2016** to approximately **13% in 2024**.
- **Average Annual Adoption Rate**: 14.7% growth was recorded year-over-year.

This trend demonstrates a gradual but committed uptake of reproducibility practices within the journal's publishing community.

5.5 Influence of Research Topic on Citations

5.5.1 Dominant Topics

Using TF-IDF (term-frequency inverse-document-frequency) and LDA (**Latent Dirichlet Allocation (LDA) topic modelling** 6 dominant topics were identified across the dataset:

- **Topic 1: Deep Learning & 3D Computer Vision**
- **Topic 2: 3D Modelling & Surface Reconstruction**
- **Topic 3: Medical Imaging & Biomedical Visualization**
- **Topic 4: Rendering & Ray Tracing**
- **Topic 5: Virtual & Augmented Reality**
- **Topic 6: Geometry Processing & Mesh Optimization**

Table 2: LDA-Derived Topic Summary—Topic Names and Top Keywords

Topic No	Topic Name	Keywords
Topic 1	3D Modelling & Surface Reconstruction	3d, based, method, paper, data, approach, propose, novel, surface, models
Topic 2	Deep Learning & 3D Computer Vision	image, 3d, computer, point, images, learning, applications, deep, processing, vision
Topic 3	Semantic Segmentation & Surface Analysis	segmentation, semantic, methods, surfaces, driving, free, field, presents, network, makes
Topic 4	Virtual & Augmented Reality	reality, virtual, augmented, 3d, ar, objects, paper, displays, tracking, vr
Topic 5	Graphics Methods & Special Issues	graphics, computer, special, section, search, main, skip, foreword, challenging, conference
Topic 6	VR Environments & Interaction	virtual, reality, vr, environments, interaction, systems, environment, data, abstract, time

5.5.2 Shift in Topic Attention Post-COVID:

- **Topic 2 (Deep Learning & 3D Computer Vision)** saw the biggest increase in share of papers, **growing by ~11.6% after-2020**.
- **Topic 1 (3D Modelling & Surface Reconstruction)** saw the largest drop, **down by ~9%.**
- Topic 3 edged up slightly, while Topics 4, 5, 6 were roughly flat or slightly down.

The following table (Table 2) and figure-9 show the growth rate of those 6 dominant topics across pre and post covid time.

Table 2: Topic Proportion Change Pre Vs Post-COVID

Topic No	Growth %
Topic 2	11.591
Topic 1	-9.083
Topic 5	-2.208
Topic 4	-0.940
Topic 3	0.881
Topic 6	-0.241

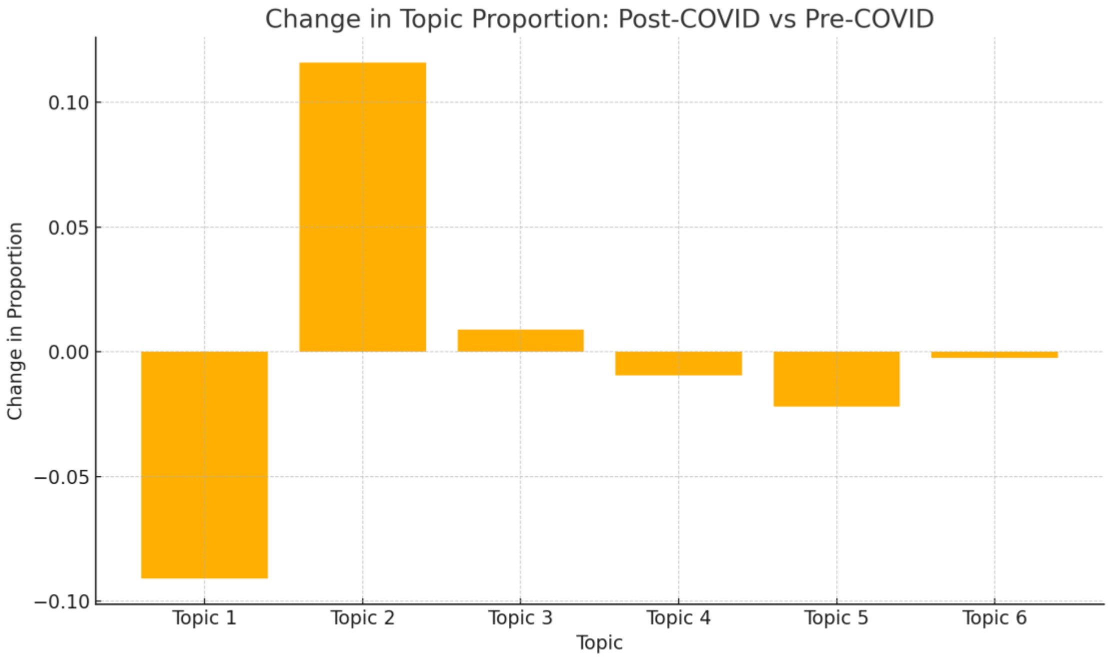

Figure 9: Proportional Change in Published Paper Volume Over Time

5.5.3 Topic Focus among Certified Replicable Group After COVID

- Among replicable papers published after 2021, **Topic 1** dominates (~40% of that subset), followed by **Topic 2** (~25%).
- The remaining topics each make up <10–10% of replicable papers.

Table: Topic Proportion Change Among Certified Group

topic	Growth %
Topic 1	40
Topic 2	25.71
Topic 4	10
Topic 6	10
Topic 3	8.57
Topic 5	5.71

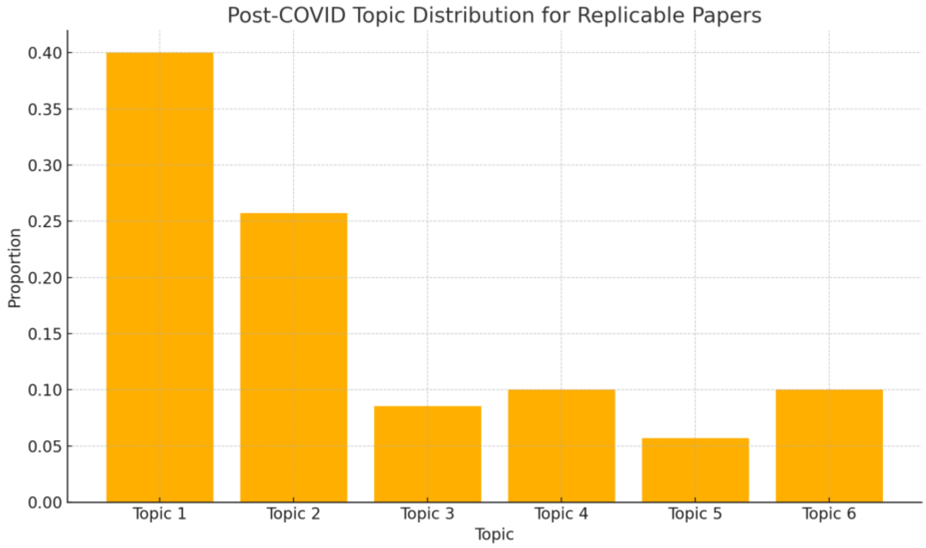

Figure 10: Proportional Change in Published Paper Volume Among Replicable Group

- **40%** of certified papers since 2021 belonged to "3D Modelling & Surface Reconstruction"—a declining citation area.
- The second-most common certified topic **(~26%)** was "Deep Learning & 3D Vision," aligning better with community trends.

Comparing both analyses, we can say that After COVID, the community shifted more into deep/computer-vision-style work (Topic 1) and away from more general "3D methods" (Topic 0). Yet, certified reproducible work remains most concentrated in the classic "3D methods" area (Topic 0) and secondarily in the "images/vision" area (Topic 2).

5.6 Author Analysis

For author analysis we looked for top 10 authors among the certified replicable group based on total citations which are as follow:

Table 3: Top 10 Authors in Certified Replicable Group

Author	Total_Citations	Mean_CitesPerYear
G Arroyo	85	10.63
T Isenberg	85	10.63
D Martin	85	10.63
A Rodriguez	85	10.63
A Raffo	76	4.934
S Biasotti	71	4.6
S Li	52	4.1
PL Rosin	48	5.4
YK Lai	45	5.4
C Romanengo	42	7

6. Answers to Business Concerns

This section directly addresses the core business concerns posed by Computers & Graphics at the outset of this project, summarizing the empirical findings derived from our data analysis and modelling.

Q1. Do research papers certified as reproducible receive more citations than non-certified papers?

Answer: No. Our analysis—including Mann-Whitney U testing and OLS regression—demonstrates that reproducibility certification is not a statistically significant predictor of higher citation counts. When controlling for confounding variables such as publication year and journal rank, certified reproducible papers do not show a significant difference in mean or median citation counts compared to non-certified papers.

Q2. Does reproducibility certification influence visibility?

Answer: Yes. Certified reproducible papers are substantially less likely to receive zero citations compared to non-certified papers. The proportion of zero-citation papers in the certified group is less than half that of the non-certified group (4.7% vs. 11.5%). Logistic regression confirms that certification reduces the probability of zero citations by ~60%, suggesting that reproducibility certification offers a clear visibility advantage.

Q3. Does reproducibility certification increase the likelihood of ranking among the top 10% most-cited papers?

Answer: No. Certification does not increase a paper's chance of ranking among the most highly cited works. In fact, a slightly higher proportion of non-certified papers fall within the top 10% of citation counts. Thus, certification's primary benefit is in mitigating low-impact outcomes, not elevating papers into the citation elite.

Q4. Does reproducibility certification accelerate a paper's initial citation momentum or annual citation rate?

Answer: Yes, to a moderate extent. Certified papers exhibit a somewhat higher average annual citation rate, particularly shortly after publication. This suggests that certification can provide early citation momentum.

Q5. Are there identifiable trends in citation trajectories or in the adoption of replicability certification?

Answer: Yes, there has been a steady increase in the adoption rate of replicability certification—from 4.26% in 2016 to nearly 13% by 2024—with an average annual growth rate of 14.7%. However, overall citation counts for all papers have declined post-2020, even as the number of published papers has increased, indicating shifting publication and citation dynamics.

Q6. Are there identifiable temporal trends in publication volume and citation counts since 2020 (COVID and post-COVID period)?

Answer: Yes.

- Publication volume increased sharply after 2020, but total citations per year dropped—especially in 2024 and 2025—indicating possible saturation and an influx of lower-impact submissions.
- Median annual citation rate for post-2020 papers is 16.5% higher than for pre-2020 papers, despite the lower total citation counts, suggesting future growth potential for newer papers.

Q7. What are the dominant thematic areas (topics) in the journal, and how have they shifted over time?

Answer: Six major topics were identified.

- Deep Learning & 3D Computer Vision has seen the largest post-pandemic increase (+11.6% since 2021).
- 3D Modelling & Surface Reconstruction saw the greatest decline (-9%).
- Other topics (Medical Imaging, Rendering, Virtual/Augmented Reality, Geometry Processing) remained steady or declined slightly.

Q8. Where is certified-reproducible work most concentrated post-COVID, and does it match new trends?

Answer: Certified reproducible work after 2021 is most common in "3D Modelling & Surface Reconstruction" (~40%), though this area is declining overall. The next most common is "Deep Learning & 3D Vision" (~26%), which matches the growing trend in the community. Certified work is thus starting to follow, but still lags, the newest trends.

Q9. Which areas should the journal target to boost both reproducibility and impact?

Answer: Focus on emerging, high-impact areas such as Deep Learning & 3D Computer Vision, where citation growth and community interest are highest. At the same time, regulate the volume and quality of published papers to counteract recent declines in overall citations and maintain the journal's influence.

7. Recommendations

Based on the analyses and findings of this study, the following recommendations are proposed for Computers & Graphics to enhance editorial strategy, support reproducibility, and maximize research impact.

1. Continued Promotion and Labeling of GRSI-Certified Papers

It is recommended that GRSI-certified papers continue to be prominently promoted and clearly labeled within the journal. The visibility advantage should be emphasized, as it has been found that certified reproducible papers are approximately 60% less likely to remain uncited. This benefit should be highlighted in calls for papers and editorial materials to encourage greater author participation.

2. Emphasis on Quality Over Quantity in Publication Acceptance

It is recommended that publication acceptance criteria prioritize quality over quantity, particularly in light of the observed increase in publication volume and simultaneous decline in total citations post-2020. Enhanced editorial screening for originality, rigor, and impact should be considered, especially during periods of high submission rates.

3. Prioritization of Certification in High-Impact, Emerging Research Areas

It is recommended that reproducibility certification be actively encouraged and prioritized in rapidly growing research fields, such as Deep Learning & 3D Computer Vision. Since these areas have demonstrated significant citation growth and align with current community interests, targeted editorial efforts in these domains are advised.

4. Regular Tracking and Analysis of Citation and Certification Trends

It is recommended that ongoing monitoring of citation metrics, zero-citation rates, topic distribution, and certification adoption be implemented through business intelligence (BI) dashboards. Insights derived from these analyses should be utilized to inform editorial decisions and the development of special issues.

5. Utilization of Topic Modelling for Editorial Planning

It is recommended that topic modelling (such as LDA and TF-IDF) be leveraged to identify emerging and declining research themes. Special issues and editorial outreach should be guided by these trends to attract high-impact submissions and maintain the journal's relevance.

6. Communication of Early Citation Advantages for Certified Papers

It is recommended that the early citation advantage and reduced risk of remaining uncited, as observed for certified papers, be clearly communicated to prospective authors. These benefits should be made transparent in journal communications to promote wider participation in certification initiatives.

7. Expansion of Collaboration with GRSI and Similar Initiatives

It is recommended that collaboration with the Graphics Replicability Stamp Initiative (GRSI) be sustained and, where possible, expanded to include additional replicability-focused organizations. Maintaining such partnerships will reinforce the journal's position as a leader in reproducible research.

8. Broadening of Certification Outreach Beyond Traditional Topics

It is recommended that targeted outreach efforts be extended beyond traditional areas such as 3D Modelling & Surface Reconstruction. Certification should be promoted in newer, fast-growing research areas to ensure alignment with evolving community interests.

9. Monitoring and Addressing Citation Decline Risks

It is recommended that the factors contributing to recent declines in total citations be closely monitored and addressed. Editorial strategies should be adapted as necessary to sustain the journal's influence and mitigate the effects of increased lower-impact submissions.

8. Deployment

Although this project was conducted as a research-focused data analysis rather than a deployed technical product, the findings and methods developed could inform future editorial decisions, reporting tools, and ongoing data initiatives at *Computers & Graphics*. Below, we outline opportunities for applying these insights and expanding the project further.

8.1 Practical Deployment Opportunities

Several components of this project could be adapted into lightweight, scalable tools or dashboards:

- **Citation and Reproducibility Dashboard:** A live dashboard could track reproducibility adoption rates, citation trends over time, and median citation gaps between certified and non-certified papers. Filters by publication year, topic cluster, and journal rank would support editorial and strategic insights.
- **Topic Trend Tracker:** Building on our LDA analysis, a tool could identify emerging "hot topics" (e.g., LLMs, AI) early and highlight reproducibility patterns within them. This would help the journal focus outreach or special issues on high-impact areas.
- **Reviewer Support Tool:** Insights from co-authorship networks and keyword clustering could assist in reviewer assignment and in identifying under-reviewed subfields or thought leaders in specific research areas.

8.2 Long-Term Strategy and Future Work

Based on the project outcomes and remaining questions, we see several areas for future research or development:

- **Altimetric Integration:** Incorporating social signals (e.g., blog mentions, GitHub stars, educational use) could help assess non-traditional forms of research visibility and show how reproducibility affects broader dissemination.
- **Open Access and Code Availability:** Expanding the dataset to include open access status, GitHub links, and supplementary materials could reveal how accessibility interacts with citation performance.
- **Forecasting Citation Trajectories:** Using early citation data (e.g., in the first year) to forecast long-term performance and identify which reproducible papers are likely to become high-impact over time.

8.3 Reflections

This project provided our team with hands-on experience in handling real-world academic data, merging and aligning disparate sources, and building robust statistical pipelines under uncertainty. It also highlighted the complexities of academic impact beyond citation counts—where topic, timing, and transparency intersect in subtle ways.

We believe this analysis can serve as a foundation for future data-informed strategy at Computers & Graphics, supporting both its reputation for research quality and its leadership in reproducibility.

9. Difficulties Encountered

Throughout the course of the project, our team encountered several technical and analytical challenges that impacted both workflow and timing. Despite these, we successfully adapted through collaboration, method changes, and contingency planning.

9.1 Dataset Integration and DOI Resolution

The initial challenge was merging citation data with reproducibility records due to missing or inconsistent DOIs. Many papers lacked a shared identifier, making alignment difficult. This was resolved through automated DOI lookups using CrossRef and OpenAlex APIs, allowing us to recover over 90% of the missing links.

9.2 Skewed Citation Distribution

Citation data was highly skewed, with many low-cited papers and a few highly cited ones. This violated assumptions of normality for standard regression models. To address this, we used **non-parametric tests** (Mann–Whitney U), **bootstrap resampling**, and **quantile regression** to ensure statistical robustness.

9.3 Small Sample of Reproducible Papers

The relatively small number of reproducible papers limited statistical power, especially for subgroup analysis (e.g., by topic or year). We addressed this by applying **bootstrapped comparisons** and focusing on **median-based summaries**, which are more reliable with skewed data.

9.4 Text and Topic Modelling Complexity

Performing topic modelling on short abstracts introduced challenges in signal quality and interpretability. We iteratively refined our **LDA model parameters** and conducted **manual topic labelling** to improve the clarity and usefulness of results.

9.5 Time Constraints

Delays in the early data cleaning and merging stages compressed the timeline for modelling and visualisation. We resolved this by assigning concurrent tasks to different team members, holding focused sync-ups, and prioritising high-impact analyses for the final report.

10. Appendix

This table below explains details for various attributes within our merged dataset.

Attributes	Description
Cites	Total number of citations received by the paper.
Authors	List of all authors credited for the paper.
Title	The full title of the paper.
Year	Year the paper was published.
GSRank	Google Scholar ranking of the journal where the paper was published (lower = better).
DOI	Digital Object Identifier to uniquely identify each paper.
CitesPerYear	Citation count divided by the age of the paper (i.e., normalised citation rate per year).
CitesPerAuthor	Citation count divided by the number of authors (to normalise for collaboration size).
AuthorCount	Number of authors who contributed to the paper.
Age	Age of the paper in years since publication.
Abstract	The abstract text summarising the content of the paper
Reproducible	Indicates reproducibility status: **0 = non-reproducible, 1 = reproducible.**