

Effectiveness of E-learning versus Conventional Museum-based Teaching in Pathology Education: A Prospective Interventional Study

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ABSTRACT

Introduction: Conventional pathology museums are invaluable resources for teaching the pathophysiology of disease through preserved pathological specimens. However, their use has declined due to the rise of web-based learning and logistical constraints such as limited time, fixed schedules, and staff shortages.

Aim: To modernise pathology museum teaching by designing, developing, and implementing innovative digital practices and to compare their effectiveness with conventional pathology museum-based teaching.

Materials and Methods: The present prospective interventional study was conducted at SRM Medical College Hospital and Research Centre, Kattankulathur, Kanchipuram, Tamil Nadu, India. Phase II MBBS students were randomly assigned into two groups. The experimental group (n=63) received QR code-assisted teaching, while the control group (n=63) received conventional museum-based teaching on cutaneous malignant tumours. An E-learning module was developed using the Analyze, Design, Develop, Implement, and Evaluate (ADDIE) model, which comprises analysis, design, development,

implementation, and evaluation stages, and was integrated with Kern's six-step approach to curriculum development. Learning effectiveness was assessed by comparing pretest and post-test scores. Categorical outcomes were analysed using the Chi-square test, while ordinal outcomes and multi-group comparisons were evaluated using Analysis Of Variance (ANOVA).

Results: Among the participants, 69 students (54.7%) reported visiting the pathology museum rarely. The E-learning group demonstrated significantly greater improvement in mean knowledge scores (4.57 ± 1.97) compared with the conventional teaching group (3.24 ± 1.97) ($p=0.0001$). Confidence in the effectiveness of E-learning pedagogy was high, with 65 students (51.58%) expressing positive perceptions.

Conclusion: Technology-enhanced learning was significantly more effective than conventional teaching methods in enhancing pathology knowledge acquisition. Digitalisation should therefore complement physical pathology museums by preserving the tactile and visual benefits of specimen-based learning while leveraging technology to improve accessibility, engagement, and educational effectiveness.

Keywords: Cutaneous malignant tumour, E-learning strategies, Pathology museum education

INTRODUCTION

The primary goal of pathology education is to help medical students comprehend the pathophysiology of diseases, thereby enabling a deeper understanding of clinical manifestations and management strategies. Traditionally, medical colleges have taught pathology through clinical autopsies, didactic lectures, theoretical and practical exercises, and the display of microscopic and macroscopic specimens in pathology museums [1].

Despite their established educational value, the utilisation of pathology museums has markedly declined due to advancements in web-based learning and information technology [2]. Additionally, increased curricular demands, time constraints, fixed schedules, growing student numbers, and limited teaching staff have further reduced museum-based instruction [3]. Consequently, many medical college museums have closed, with some institutions donating exhibits and repurposing museum spaces into classrooms or laboratories [1].

The objective of digitisation should not be to replace physical museums but to enhance their educational impact by improving accessibility and comprehension of pathological knowledge [4]. Studies by Vimal S et al., Chaudhari P et al., and Rathod G et al., have demonstrated that integrating innovative teaching modalities such as virtual microscopy and digital museum-based learning-

into undergraduate pathology education in India improves student engagement, visual understanding, and learning outcomes when used alongside conventional teaching [5-7].

Furthermore, Baurau K et al., highlighted the expanding role of E-learning and blended learning in Indian medical education, emphasising both opportunities for flexible learning and challenges related to infrastructure, faculty training, and learner preparedness [8]. However, there remains limited Indian evidence on curriculum-aligned digital augmentation of physical pathology museums as a blended learning strategy. Therefore, the present study addresses this gap by proposing a digitally enhanced, learner-centred pathology museum model aligned with competency-based medical education to improve student engagement and comprehension of disease pathophysiology.

The present study aimed to design, develop, and implement E-learning strategies for pathology museum teaching and to compare their effectiveness with conventional museum-based teaching.

MATERIALS AND METHODS

The present prospective interventional study was conducted among Phase II MBBS students between December 2023 and February 2024 at SRM Medical College Hospital and Research Centre,

Kattankulathur, Kanchipuram, Tamil Nadu, India. Approval was obtained from the Institutional Scientific Committee and Institutional Ethics Committee (SRMIEC-STO922-192).

Inclusion and Exclusion criteria: Students who were willing to participate, provided informed consent and maintained attendance above 85% were included in the study. Students who declined participation or did not provide consent were excluded.

Participants were initially enrolled using convenience sampling based on availability during the study period. Subsequently, simple random sampling was used to allocate students into study groups to ensure unbiased assignment.

Study Procedure

Development of the E-learning module: An E-learning module on cutaneous malignant tumours specifically squamous cell carcinoma, basal cell carcinoma, and malignant melanoma was developed using the instructional design model ADDIE, integrated with Kern’s six-step approach to curriculum development. Kern’s framework guided systematic needs assessment, goal and objective formulation, selection of educational strategies, implementation, and evaluation in alignment with competency-based medical education principles [9].

Analysis phase: A comprehensive needs assessment [10] was conducted by reviewing the existing syllabus and mapping required

competencies according to National Medical Commission guidelines to identify curriculum gaps for the selected topic of cutaneous malignant tumours. Learner analysis was performed through a pre-study survey assessing museum visit frequency, baseline knowledge, smartphone access, and digital literacy.

Context and constraint analysis included evaluation of museum schedules, specimen availability, and infrastructure such as internet connectivity and Wi-Fi access. Task analysis was carried out by a panel of subject experts who validated the E-learning module [Table/Fig-1a,b] and the questionnaire. Competencies were broken down into teachable components, and corresponding assessment questions were formulated.

Design phase: The identified competencies were systematically divided into teachable units covering clinical presentation, gross morphology, microscopic features, and prognostic aspects of cutaneous malignant tumours. The assessment strategy included pretest and post-test evaluations, along with a structured feedback questionnaire.

Development phase: The E-learning resources comprised QR codes affixed to museum specimens of cutaneous malignant tumours. These codes linked to Google Docs containing concise explanatory text, labelled images, and embedded instructional videos.

Squamous cell carcinoma

- Cutaneous squamous cell carcinoma is a most common malignant tumour arising from epidermal keratinocytes.
- Most often in sun exposed areas.
- **Etiopathogenesis:** Ultraviolet light radiation, Chronic immunosuppression, Actinic keratosis, Burn scars, chronic ulcers, Chronic inflammation, Simus tract, Human papillomavirus infection, Xeroderma pigmentosum.
- UV radiation, mutations involving genes (such as *TP53*, *CDKN2A*, *NOTCH1* and *NOTCH2*, *EGFR* and *TERT*) and molecular pathways (*RAS* / *RAF* / *MEK* / *ERK* and *PI3K* / *AKT* / *mTOR*) have been shown to play an important role in the pathogenesis.
- Tumour suppressor gene (*TP53* gene) ensures that cells repair any damaged DNA before cell division by inducing cell cycle arrest to allow time for DNA repair or to force the cell to undergo apoptosis via activation of *BAX* gene
- **Gross appearance:** This tumour presents an infiltrative growth pattern with a peculiar fungating configuration that is often compared to a cauliflower.

- **Microscopy:** carcinoma of keratinocytes that infiltrates the dermis.
 - Well differentiated: easily recognizable squamous epithelium, abundant keratinization, intercellular bridges apparent, minimal pleomorphism, mitotic

include absence of maturation, increased dermal mitotic activity and tumour necrosis.

- **Cytologic features:** Epithelioid / spindle shaped cell, Nuclear pleomorphism, enlargement, hyperchromasia, Coarse irregular chromatin pattern with peripheral condensation (pepper moth nuclei), prominent eosinophilic nucleoli and dusty pigmented cytoplasm
- **Stromal changes:** Dermal fibrosis, irregular distribution of pigment

Prognostic factors:

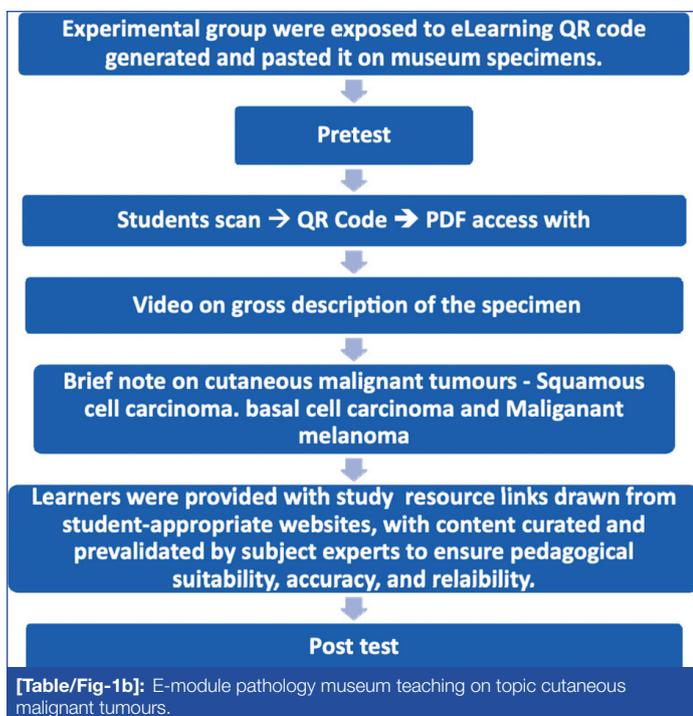
- **Favourable prognostic factors:** young age, female, low risk sites: extremities, early stage melanomas, brisk tumour infiltrating lymphocytes.
- **Unfavourable prognostic factors:** Elderly patients, Male, High risk sites: back, upper arm, head and neck and acral sites, High Breslow depth, Positive sentinel lymph node biopsy, High dermal mitotic rate and Ulceration.

Further reference:
<https://www.pathologyoutlines.com/topic/skintumormelanocyticmelanoma.html>

Post test:
https://docs.google.com/forms/d/e/1FAIpQLSfEZLrfeuY0tAqfCrmvb3yX_uVbmlRCf0rRkdLYMID-It-IA/viewform?usp=sf_link

Feedback :
https://docs.google.com/forms/d/e/1FAIpQLSct5sCxJ2aty10J0yMsYwYfRcTnE0ETOwgMQAFg8vjZFJEVw/viewform?usp=sf_link

[Table/Fig-1a]: E-module pathology museum teaching on topic cutaneous malignant tumours.



Content development, QR code generation, pilot testing, faculty training, and ethical compliance checks were completed during December 2023.

Implementation phase: Phase II MBBS students were recruited after obtaining written informed consent. Participants were randomly assigned using simple random sampling into two groups: the experimental group, which received QR code-assisted instruction, and the control group, which underwent conventional museum-based teaching on cutaneous malignant tumours.

Faculty orientation sessions were conducted to train instructors on facilitating museum-based learning, administering pretests and post-tests, and collecting structured feedback. Session logistics were standardised across both groups. A pretest was administered to all participants immediately before instruction using a secure online format.

The control group received traditional faculty-led teaching using physical specimens, while the experimental group accessed QR-linked digital learning resources. Faculty served as facilitators, clarifying concepts and guiding clinical correlations during sessions. After the instructional period, both groups completed the post-test.

The pretest and post-test each comprised 15 multiple-choice questions assessing knowledge related to aetiopathogenesis, clinical features, gross pathology, histopathology, and prognosis. Each correct answer was awarded one mark, with no negative marking, yielding a maximum possible score of 15.

Following completion of the study, the E-learning module and related resources were shared with the control group, and the experimental group was subsequently exposed to conventional museum-based teaching to ensure educational equity. Feedback was collected from both groups.

Monitoring measures included tracking attendance, QR code scan frequency, time spent per specimen, and documentation of technical issues. Roles and responsibilities were clearly defined among the Principal Investigator, faculty members, research assistants, and IT support personnel. Recruitment, consent, and initial museum sessions with pretesting occurred in January 2024. The intervention concluded in February 2024 with post-testing, feedback collection, data entry, and initiation of statistical analysis.

The feedback questionnaire consisted of four semi-open-ended questions and three closed-ended questions. It was internally

developed based on established educational literature and validated constructs from E-learning evaluation frameworks [11,12]. The tool was synthesised from existing validated instruments. Content and construct validity, as well as reliability (internal consistency), were established through a pilot study involving 10% of the sample (n=13) prior to the main study. The Cronbach's alpha value was 0.86, indicating good internal consistency.

Evaluation phase: Evaluation within the ADDIE framework was conducted as a continuous and iterative process, incorporating both formative and summative components.

Formative evaluation focused on monitoring process fidelity and technical functionality during early implementation. QR code performance and Google Doc accessibility were routinely checked, with any issues promptly logged and resolved. Student feedback regarding ease of scanning and clarity of materials, along with faculty observations on session flow, were collected. Module completion rates and video viewing durations were tracked where analytics were available to assess learner engagement.

Summative evaluation assessed the overall effectiveness of the intervention following study completion by comparing learning outcomes between the experimental and control groups. Additional process metrics- including QR scan frequency, median time spent per document, and video completion rates- provided insights into learner engagement and implementation fidelity. A structured feedback mechanism was used to refine instructional materials. Based on analysis results and formative observations, revisions were made to Google Doc content, embedded videos, and facilitation guidelines to ensure continuous quality improvement in future iterations.

STATISTICAL ANALYSIS

Data were coded, anonymised, and entered into Statistical Package for Social Sciences (SPSS) version 26 for analysis. Categorical variables were analysed using the Chi-square test, while ordinal outcomes and multi-group comparisons were evaluated using ANOVA. A p-value of less than 0.05 was considered statistically significant.

RESULTS

A total of 126 Phase II MBBS students participated in the study (63 in the control group and 63 in the experimental group), with a mean age of 20.3±1.1 years and an overall male-to-female ratio of 1.5:1. While 120 students (95.23%) possessed adequate baseline pathology knowledge regarding cutaneous malignant tumours, 103 (81.74%) lacked understanding of the diagnostic criteria for malignant cutaneous lesions. It was observed that 113 participants (89.68%) demonstrated practical ability to search for and access the E-learning module with ease. All participants owned smartphones, facilitating the digital intervention.

The majority of students reported visiting the pathology museum rarely (n=69, 54.76%) or occasionally (n=36, 28.57%). Only a negligible proportion (n=2, 1.58%) reported frequent visits, highlighting the underutilisation of traditional museum resources [Table/Fig-2].

Both study groups demonstrated significant improvements in knowledge across all domains, including aetiopathogenesis, clinical presentation, and microscopy. However, the experimental group achieved higher post-test mean scores (11.08) compared with the control group (10.16). Correct responses related to specific microscopic features increased from 46.82% (n=59) at baseline to 85.71% (n=108) post-intervention [Table/Fig-3].

The E-learning approach produced a significantly greater mean score improvement (4.57) than the conventional method (3.24). This statistically significant difference (p=0.0001) indicates that the technology-enhanced strategy was more effective in improving student knowledge [Table/Fig-4].

How often do you visit pathology museum?	Total
Frequently	2 (1.6%)
Never	19 (15.1%)
Occasionally	36 (28.6%)
Rarely	69 (54.7%)
Total	126 (100%)

[Table/Fig-2]: Frequency of museum visits.

Group	Pretest		Post-test		p-value
	Mean	SD	Mean	SD	
Control (n=63)	7.14	4.173	10.16	3.189	0.0001
Experimental (n=63)	6.51	3.822	11.08	2.83	0.0001

[Table/Fig-3]: Pre and post-test scores.

Group	N	Pre and post-test difference of knowledge score		p-value
		Mean	SD	
Conventional	63	3.24	1.97	0.0001
E-learning	63	4.57	1.97	

[Table/Fig-4]: Effectiveness of conventional and E-learning methods on knowledge improvement using the pre and post-test difference in scores.

Students valued conventional museum teaching primarily for hands-on experience and direct interaction with specimens (n=34, 26.98%), but reported significant logistical challenges related to scheduling and limited access. In contrast, the E-learning method was preferred for resource accessibility (n=32, 25.39%) and flexibility in revisiting content, although technical issues and challenges in maintaining individual motivation were noted [Table/Fig-5a-d].

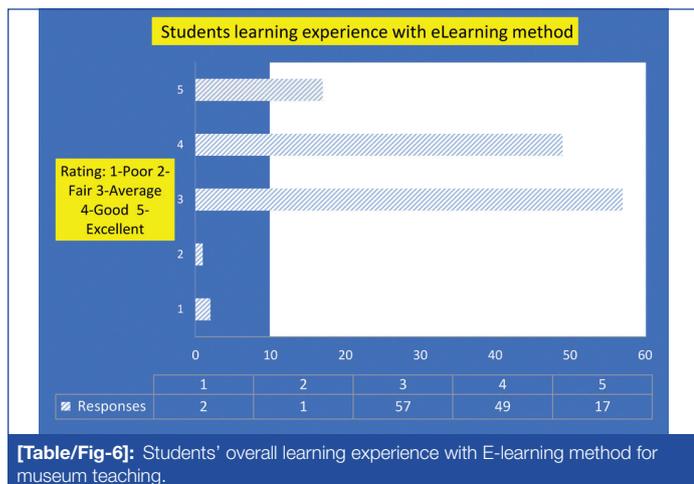
a) What are the advantages of Conventional museum pedagogy	Conventional method	
	n	%
Direct interaction with artifacts	26	20.6
Direct interaction with artifacts, guided tours by experts	8	6.3
Direct interaction with artifacts, opportunity for group discussions, guided tours by experts	2	1.6
Guided tours by experts	4	3.2
Hands-on experience	14	11.1
Hands-on experience, direct interaction with artifacts	13	11.1
Hands-on experience, direct interaction with artifacts, guided tours by experts	6	4.8
Hands-on experience, direct interaction with artifacts, opportunity for group discussions	8	6.3
Hands-on experience, direct interaction with artifacts, opportunity for group discussions, guided tours by experts	34	27.0
Hands-on experience, opportunity for group discussions	2	1.6
Opportunity for group discussions	9	6.3
Total	126	100.0
b) What challenges do you face with conventional pedagogy	Traditional	
	n	%
Difficulty in scheduling visits	38	30.2
Difficulty in scheduling visits, lack of flexibility in learning pace	8	6.3
Difficulty in scheduling visits, lack of interactive learning materials	4	3.2
Lack of flexibility in learning pace	8	6.3
Lack of interactive learning materials	4	3.2
Limited access to museums	34	27.0
Limited access to museums, difficulty in scheduling visits	12	9.5
Limited access to museums, difficulty in scheduling visits, lack of flexibility in learning pace	4	3.2
Limited access to museums, difficulty in scheduling visits, lack of interactive learning materials, lack of flexibility in learning pace	12	9.5

Limited access to museums, lack of flexibility in learning pace	2	1.6
Limited interaction with artifacts	0	0.0
Total	126	100.0
c) What are the advantages of E-learning pedagogy	E-learning	
	n	%
Ability to revisit materials	24	19.0
Access to a wide range of resources	32	25.4
Access to a wide range of resources, ability to revisit materials	6	4.8
Access to a wide range of resources, interactive multimedia content	2	1.6
Access to a wide range of resources, interactive multimedia content, ability to revisit materials	6	4.8
Flexibility in learning schedule	12	9.5
Flexibility in learning schedule, ability to revisit materials	4	3.2
Flexibility in learning schedule, access to a wide range of resources	2	1.6
Flexibility in learning schedule, access to a wide range of resources, ability to revisit materials	10	7.9
Flexibility in learning schedule, access to a wide range of resources, interactive multimedia content, ability to revisit materials	14	11.1
Flexibility in learning schedule, interactive multimedia content	2	1.6
Interactive multimedia content	8	6.3
Interactive multimedia content, ability to revisit materials	4	3.2
Total	126	100
d) What challenges do you face with E-learning pedagogy	E-learning	
	n	%
Difficulty in staying motivated	16	12.7
Lack of hands-on experience	16	12.7
Lack of hands-on experience, difficulty in staying motivated	4	3.2
Lack of hands-on experience, limited interaction with artifacts	22	17.5
Lack of hands-on experience, limited interaction with artifacts, difficulty in staying motivated	6	4.8
Limited interaction with artifacts	18	14.3
Limited interaction with artifacts, difficulty in staying motivated	4	3.2
Technical difficulties	14	11.1
technical difficulties, difficulty in staying motivated	2	1.6
technical difficulties, lack of hands-on experience	8	6.3
technical difficulties, lack of hands-on experience, difficulty in staying motivated	4	3.2
technical difficulties, lack of hands-on experience, limited interaction with artifacts	2	1.6
Technical difficulties, lack of hands-on experience, limited interaction with artifacts, difficulty in staying motivated	6	4.8
Technical difficulties, limited interaction with artifacts	2	1.6
Technical difficulties, limited interaction with artifacts, difficulty in staying motivated	2	1.6
Total	126	100.0

[Table/Fig-5a-d]: Students perception on advantages and challenges with conventional museum teaching and E-learning method.

Confidence in the effectiveness of E-learning pedagogy was high, with 65 participants (51.58%) responding affirmatively. A substantial proportion remained uncertain (n=49, 38.89%), while only 12 students (9.52%) considered the method ineffective. Learners in both groups expressed a preference for E-learning over conventional pedagogy, including 43 students (68.25%) in the experimental group and 39 students (61.90%) in the control group, suggesting broad acceptance of digital learning approaches.

Overall experience with E-learning was rated positively, with 57 students (45.2%), 49 students (38.9%), and 17 students (13.5%) assigning ratings of 3, 4, and 5, respectively, on a 5-point Likert scale. Very few participants expressed dissatisfaction, with only two students (1.6%) rating it as one and one student (0.8%) rating it as two [Table/Fig-6].



[Table/Fig-6]: Students' overall learning experience with E-learning method for museum teaching.

DISCUSSION

The present study demonstrated a clear pedagogical advantage of technology-assisted learning over traditional museum-based instruction. The experimental group exhibited a significantly greater improvement in knowledge scores compared with the control group ($p=0.0001$), with consistent superiority across all key domains, including aetiopathogenesis, clinical features, macroscopy, microscopy, and prognosis of cutaneous malignant tumours.

These findings are consistent with those of Barua K et al., who reported that E-learning modules significantly enhance knowledge acquisition in pathology [8]. Similarly, smartphone-based educational interventions reported by Niromand E et al., and systematic reviews by Naveed QN et al., have shown that mobile learning often produces superior or comparable learning outcomes relative to conventional teaching in higher education [13,14].

The integration of Quick Response (QR) codes meets the learning preferences of contemporary digitally proficient students by providing immediate access to concise content and multimedia resources [15]. In the Indian context, the results align with interventional studies demonstrating that QR code-assisted museum learning enhances student engagement, comprehension, and motivation [14]. Furthermore, studies by Niromand E et al., and Mahesh Kumar U et al., reported that instant access to labelled images and instructional videos supports diagnostic reasoning and application-based learning [13,16].

Regarding learner perceptions, the majority preferred E-learning (68.3% in the experimental group and 61.9% in the control group), describing digital systems as innovative, flexible, convenient, and effective. These findings echo those of Sreedharan S et al., who noted declining reliance on traditional museum pedagogy due to logistical challenges [17]. In the present study, scheduling difficulties (30.2%) and limited access (27%) were key barriers contributing to infrequent museum visits. Lakhtakia R similarly observed that digital platforms overcome such barriers by enabling "anytime, anywhere" learning [18].

However, the study also highlights the limitations of purely digital approaches. Participants cited reduced hands-on experience and limited interaction with physical specimens (17.5%) as disadvantages of E-learning. Since traditional museums foster tactile learning, emotional engagement, and clinical realism, a blended learning model-combining digital accessibility with physical specimen exposure-emerges as the optimal educational strategy. This conclusion aligns with previous findings by Sreedharan S et al., [17].

A major strength of this study lies in its methodological rigor. The E-learning module was developed using structured instructional design frameworks (ADDIE and Kern models), ensuring learner-centred design and educational coherence. Moreover, equitable learning opportunities were ensured by providing digital resources to the control group after assessment.

Limitation(s)

The study has several limitations. It was conducted at a single institution and focused exclusively on Phase II MBBS students, which may limit generalisability. Additionally, only immediate learning outcomes were assessed. Future studies should employ multicentre designs and longitudinal follow-up to evaluate long-term knowledge retention, clinical application, and sustained learner engagement.

CONCLUSION(S)

The present study demonstrates that the E-learning approach was more effective than conventional museum-based teaching in enhancing pathology knowledge. The majority of students favoured a blended instructional model integrating digital museum resources-such as QR-enabled systems- with traditional specimen-based learning. Such an approach preserves the historical and tactile value of pathology museums while leveraging technology to improve accessibility, engagement, and knowledge retention. This balanced educational strategy ensures that pathology teaching remains relevant, interactive, and clinically meaningful, reinforcing the critical link between basic science and medical practice.

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