



Virtual museums: a tool for studying traditional Indonesian musical instruments

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Abstract. *Introduction.* Immersive virtual reality has the potential to expand access to traditional musical instruments for a broader audience, including individuals who cannot directly master these instruments. *Aim.* The present paper aims to investigate teachers' perceptions of the pedagogical affordances of the EduLaras Virtual Museum, a virtual museum of West Javanese musical instruments. *Methodology and research methods.* Thirty-two arts and culture teachers, selected through purposive sampling, completed a 37-item questionnaire based on the UTAUT and TPACK frameworks, as well as the standard System Usability Scale (SUS). They also responded to five open-ended questions following a trial session at the museum. Perceptions of the museum were assessed using three UTAUT constructs: performance expectancy (the belief that the museum would enhance work effectiveness), effort expectancy (the ease of learning and using the system), and social influence (perceived support from colleagues, management, and educational norms). The analysis included descriptive statistics of the ratings, evaluation of the SUS with internal consistency assessed as a pilot indicator, and qualitative content analysis of the open-ended responses. *Results.* All three UTAUT constructs – performance expectancy ($M = 3.94$, $SD = 0.60$), effort expectancy ($M = 3.78$, $SD = 0.68$), and social influence ($M = 3.82$, $SD = 0.65$) – exceeded the facilitating conditions for adopting the proposed technology. This suggests a strong perception of the museum's usefulness and ease of use, as well as perceived support from significant others, whereas the organisational and technical infrastructure received lower ratings. The SUS score was high ($M = 90.23$, $SD = 9.49$; median = 92.50; range = 62.50–100; $\alpha = 0.938$), with 21 participants scoring at least 90 and six achieving a perfect score of 100. This distribution indicates a pronounced ceiling effect. Qualitative analysis revealed that the most frequently cited benefits were instructional support (18/32) and engagement (15/32), while anticipated barriers included resources, access, and cost (23/32), as well as training and adaptation (13/32). *Scientific novelty.* A gap was identified between ease of use and readiness for adoption. Although the museum appeared easy to use during the introductory session, this did not necessarily indicate readiness to integrate it into the teaching process. Such readiness depended on organisational resources, pedagogical integration, and management support. *Practical significance.* The practical significance lies in the shared use of virtual reality equipment, the provision of short-term training and support when challenges arise, and the iterative testing of acoustic, rhythmic, and simulation activities.

Keywords: virtual reality, virtual museum, teacher pilot study, West Java, traditional music, perceived usability, UTAUT, TPACK

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Виртуальные музеи как способ изучения традиционных музыкальных инструментов Индонезии

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Аннотация. *Введение.* Иммерсивная виртуальная реальность способна расширить доступ к традиционным музыкальным инструментам для более широкой аудитории, включая тех, для кого прямое освоение этих инструментов недоступно. *Цель* – исследовать восприятие преподавателями педагогических возможностей виртуального музея западно-яванских музыкальных инструментов (EduLaras Virtual Museum). *Методология, методы и методики.* 32 преподавателя искусства и культуры, отобранные методом целенаправленной выборки, после пробного сеанса работы в музее заполнили опросник из 37 пунктов по шкалам UTAUT и TPACK, стандартную шкалу SUS и ответили на пять открытых вопросов. Восприятие музея оценивалось через три конструкта UTAUT: ожидание производительности (уверенность в том, что музей повысит эффективность работы), ожидание усилий (насколько легко освоить и использовать систему) и социальное влияние (ощущение поддержки со стороны коллег, руководства и образовательных норм). Анализ включал также описательную статистику оценок, SUS (проверку внутренней согласованности как пилотного показателя) и качественный контент-анализ открытых ответов. *Результаты.* Все три конструкта UTAUT превысили условия, облегчающие внедрение предлагаемой технологии: ожидание производительности ($M = 3,94$; $SD = 0,60$), ожидание усилий ($M = 3,78$; $SD = 0,68$) и социальное влияние ($M = 3,82$; $SD = 0,65$). Это говорит о высокой оценке полезности и удобства музея и о воспринимаемой поддержке со стороны значимых других, тогда как созданная организационно-техническая инфраструктура оценивалась ниже. Показатель SUS оказался высоким ($M = 90,23$; $SD = 9,49$; медиана = 92,50; размах = 62,50–100; $\alpha = 0,938$), причем 21 участник набрал не менее 90 баллов, а шестеро – 100. Такое смещение оценок к верхней границе шкалы свидетельствует о выраженном «эффекте потолка». Качественный анализ показал, что преимуществами чаще всего называли учебную поддержку (18/32) и вовлеченность (15/32), а ожидаемыми барьерами – ресурсы, доступ и стоимость (23/32), а также обучение и адаптацию (13/32). *Научная новизна.* Выявлен разрыв между удобством использования и готовностью к внедрению. Музей показался удобным на ознакомительном сеансе, однако это не означало готовности включить его в учебный процесс. Такая готовность зависела от организационных ресурсов, педагогической интеграции и управления. *Практическая значимость* связана с совместным использованием оборудования виртуальной реальности, организацией краткосрочного обучения и поддержки при затруднениях, а также итеративной проверкой акустических, ритмических и симуляционных активностей.

Ключевые слова: виртуальная реальность, виртуальный музей, пилотное исследование с участием учителей, Западная Ява, традиционная музыка, воспринимаемое удобство, UTAUT, TPACK

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Introduction

Rapid technological developments have transformed education, including the fields of cultural heritage and music education [1]. M. M. Asad, A. Naz, P. Churi et al. [2], and E. Hu-Au and J. J. Lee [3] state that the emergence of Virtual Reality (VR) as a pedagogical tool represents a major innovation, while G. Makransky, N. K. Andreasen, S. Baceviciute et al. [4] affirm that this tool can enhance the learning experience. Learning musical instruments using VR in Indonesia highlights a revolutionary educational method, which makes the interaction between users and their cultural heritage happen in an unprecedented way. VR offers users a unique experience and also enhances their perception and feelings, in which they can feel as though they are in a virtual environment. Virtual museums are essential in preserving and advancing intangible cultural heritage of Indonesian musical instruments, which are often threatened to be displaced by globalised contemporary cultural expressions. In accordance, D. Miharja [5] conveys that Indonesian people consider their musical traditions manifest artistic innovation and their spiritual and historical identity. P. Hronček, B. Gregorová, D. Tometzová et al. [6] state that virtual products are typically used for reconstruction of tourism and cultural heritage, also for preservation [7], documentation [8], and cultural heritage [9]. Understanding technology acceptance is becoming increasingly important as global education embraces new technologies. The Unified Theory of Acceptance and Use of Technology (UTAUT) model, developed by V. Venkatesh, J. Thong, and X. Xu [10], provides a comprehensive framework to explain this phenomenon. According to UTAUT, there are four fundamental factors influencing technology acceptance: Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), and Facilitating Conditions (FCs). These factors affect an individual's propensity to adopt and use technology.

Immersive virtual reality (I-VR) is a head-mounted, controller-mediated three-dimensional environment that lets users look around, move, manipulate virtual instruments, and receive coordinated visual and auditory feedback. A virtual museum is not merely a digital repository or a three-dimensional replica of a physical collection; rather, it is a curated digital heritage environment that selects and organises artefacts, sound, narratives, contextual information, and interactive elements to facilitate the mediation of cultural knowledge. In this study, technological competence is distinguished from general educational digital competence by its focus on VR-specific operational ability: using a headset and controllers and addressing basic technical issues. Pedagogical knowledge encompasses teachers' understanding of instructional strategies, classroom organisation, scaffolding, and assessment. Behavioural intention is defined as an individual's stated plan or will-

ingness to use a technology in the future. As the current teacher instrument did not include dedicated behavioural intention or actual-use items, neither construct is considered an outcome in this pilot study.

Within the above framework, W. Moughal, S. M. Nordin, R. Salleh et al. [11] state that PE relates to the perceived benefits of technology in improving job performance, while EE addresses the ease of use of the technology. In comparison, H. Khechine, B. Raymond, and M. Augier [12] highlight that SI emphasises the importance of the perspectives of peers and significant others in the adoption process, while L. L. Zhou, J. Owusu-Marfo, H. Asante Antwi et al. [13] demonstrate that FCs are associated with the availability of resources and support systems that enable the effective use of technology. A study by Z. Tong [14] reports that research in music education reveals that musicians generally display favourable attitudes towards technology. A significant gap exists in understanding how teachers, especially in non-Western contexts, modify tools like VR for classroom use. This is particularly relevant in Indonesian music education in which traditional methods might need modernisation to keep up with contemporary technology.

In the context of VR-based virtual museums for traditional musical instruments, performance expectancy (PE) refers to teachers' perceptions of the virtual museum's usefulness for explaining instruments, supporting cultural learning, and enriching teaching tasks. Effort expectancy (EE) addresses the perceived difficulty associated with learning and operating the headset, controllers, navigation, and application. Social influence (SI) pertains to encouragement or expectations from colleagues, school leaders, learners, musicians, and cultural communities. Facilitating conditions (FC) relate to the availability of devices, time, training, technical assistance, connectivity, and institutional support. System Usability Scale (SUS) is reported separately as a global measure of perceived usability during the facilitated first-use session. In this pilot, UTAUT and TPACK domains organise descriptive and qualitative interpretation; they are not modelled as latent causal predictors.

In addition to UTAUT, Technological Pedagogical Content Knowledge (TPACK) provides an essential perspective for analysing the convergence of technology, pedagogy, and content knowledge [15]. According to F. Cipta, Y. Sukmayadi, R. Milyartini et al. [16], TPACK is particularly relevant in music education, and D. Stoilescu [17] supports that TPACK allows teachers to manage the intricacies of teaching musical concepts while skilfully integrating technology into their teaching. Indonesian music teachers must be able to play and teach Indonesian musical instruments and be proficient in using technologies to enhance their students' learning experience. However, M. M. A. Latif and M. M. Alhamad [18] raised an issue related to unproficiency in technology devices, training, and support becomes an issue faced by teachers, obstructing the successful technology integration in their classrooms such as unfamiliarity with technological devices and inadequate training and support. Thus, a successful implementation of VR-based museums necessitates a comprehensive understanding technology acceptance factor and learning strategies. According to C. K. Galla [19], VR has been used in cultural education to duplicate historical

settings, imitate investigation of archaeological, and bring extinct language back. These implementations underline capacity of VR to improve learning through interactivity and memory [20]. However, the implementation of VR in teaching traditional music, especially Indonesian traditional music, remains relatively unexplored. Additionally, M. Lui, R. McEwen, and M Mullally [21] affirm that the main focus of VR in education studies is on its cognitive benefits, including improved memory retention and conceptual understanding, but neglecting the cultural and emotional aspects of learning. Therefore, integrating VR into Indonesian music education requires a framework addressing both technological and pedagogical complexities. The transition to modern teaching methods poses significant challenges in preserving traditional music. Innovative tools are needed to engage modern learners and present traditional music in relevant ways. Despite this, S. Williams¹ reports that no interactive virtual museum has yet been dedicated specifically to West Javanese traditional music, and younger generations often prefer globalised contemporary genres to local ones. Thus, leveraging UTAUT and TPACK into VR-based museums offers valuable insights into Indonesian music teachers' perceptions and adoption of technology.

This study employs an exploratory mixed-methods teacher pilot design rather than a confirmatory test of UTAUT-TPACK pathways. The purposive sample ($n = 32$), the initial facilitated exposure, and the absence of dedicated behavioural-intention and actual-use measures preclude claims regarding causal relationships between constructs or the moderating effect of pedagogical training. Instead, the pilot focuses on the following research questions:

RQ1. What preliminary response patterns do teachers report concerning perceived usefulness, perceived effort, social support, facilitating conditions, TPACK-related readiness, and perceived first-use usability of the evaluated VR-based virtual museum?

RQ2. What benefits, barriers, enabling conditions, cultural concerns, and development priorities are identified in teachers' open-ended responses and contextual observations during initial use?

RQ3. In what ways should convergent and divergent evidence from the pilot inform the refinement of the virtual-museum prototype, the teachers' instrument, and the design of a subsequent larger study?

These research questions limit the study's inferences to formative evidence from participating teachers, whose school affiliations were primarily in West Java but varied by district and school level. The study does not assert educational effectiveness, sustained adoption, actual classroom use, or statistical representativeness of teachers in West Java. Since behavioural intention and actual use were not measured in the pilot study, the proposed hypothesis is preliminary and pertains to the next phase of the research. In the current study, it serves to shape the research questions and refine the instruments, rather than to confirm causal relationships.

¹ Williams S. Current developments in Sundanese popular music. *Asian Music*. 1989;21(1):105–136. doi:10.2307/834075

H1. Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), and Facilitating Conditions (FC) are significant predictors of teachers' Behavioural Intention (BI) to use a VR virtual museum in teaching traditional Indonesian music. At the same time, the level of TPACK (Technological Pedagogical Content Knowledge) moderates these relationships: it strengthens the effect of PE and weakens the negative effect of EE on BI.

The analytical model underlying this study treats UTAUT and TPACK as two complementary layers rather than a single merged construct set. UTAUT constitutes the acceptance layer, capturing teachers' perceived value (PE), perceived effort (EE), social endorsement (SI), and enabling resources (FC) as antecedents of behavioural intention (BI). TPACK constitutes the integration layer, describing whether teachers can translate a technically usable tool into a pedagogically and culturally coherent lesson. The two layers are connected, not interchangeable: acceptance without integration capacity risks producing a tool teachers are willing to try but do not know how to teach with, while integration capacity without acceptance risks producing pedagogically sound activities that teachers are reluctant to adopt. This connection is formalised in H1, where TPACK is positioned as a moderator of the PE–BI and EE–BI relationships rather than as a parallel predictor: a teacher's pedagogical-content integration ability is expected to amplify the effect of perceived usefulness and buffer the effect of perceived difficulty on intention to use. In the present pilot, this model is stated as a directional hypothesis for future confirmatory testing; it is not estimated here, since BI and TPACK were assessed only at the descriptive-domain level and no behavioural-intention scale was administered.

Literature Review

Experiential learning approaches to traditional music in Indonesia

Interactive learning is grounded in the constructivist and experiential learning theories proposed by D. A. Kolb, R. E. Boyatzis, and C. Mainemelis [22]. It aims to enhance interactive methodologies by fostering experiential learning, reflection, and active exploration. In music education, it helps learners to improve their technical skills and cultural appreciation in which they can engage with musical instrument directly [23]. By providing multimodal experiences, such as interactive technology within this framework, the learning outcomes can be enhanced [24]. Learners can interact with auditory, visual, and tactile stimuli and facilitate the development of cognitive and emotional associations with music. VR and augmented reality (AR) [25] are some of the most promising technologies allowing learners to learn traditional musical instruments virtually, engage with their digital versions, and practice playing them in a virtual environment that mimics the acoustics and ambiance of the cultural context. A study by T. Nurjatisari, Y. Sukmayadi, and T. Nugraheni [26] highlights the benefits of technology-assisted learning environment, particularly for young people accustomed to digital interfaces. In accordance, VR-based musical instrument learning, gamification platforms, and mobile applications enhance students' engagement, facilitate self-paced learning, and enable progress monitoring.

M. Ahmed, H. Ragab, and S. Shaker [27] emphasise 3D modelling and sound synthesis to teach traditional musical instruments overcome learning challenge and geographical limitations, and widen access to historical musical traditions.

The literature cautions against treating immersion as an educational effect in itself: a systematic review found generally promising but inconsistent affective and cognitive outcomes for immersive VR, with null results and limited evidence of retention [28], and presence or enjoyment can increase without a corresponding learning advantage [4]. The relevant question is therefore not whether VR is inherently superior, but which pedagogical, cultural, and infrastructural conditions make its affordances instructionally useful. Comparable settings offer transferable, not directly generalisable, design principles: Italian mobile-VR music education demonstrated how immersion can connect listening, place, and guided exploration [29], and research on virtual musical-instrument learning highlighted embodied interaction and visual guidance as scaffolds for actions difficult to communicate verbally [30]. Differences in learners, instruments, and cultural authority mean these outcomes cannot simply be generalised to Indonesian teachers.

Virtual museum concept on traditional musical instruments of West Java using virtual reality

Virtual museums enable visitors to engage with digital representations of historical and cultural artefacts and their contextual environments in ways unattainable by traditional museums [28]. Thus, several factors are to be considered include: VR make a replica of real world in which authentic artefacts are occasionally restricted and out of reach [29]. The virtual museum enables visitors to engage remotely with 3D renderings of musical instruments, including *gamelan degung*, *tarawangsa*, *angklung*, and others. These contents are presented in forms of historical timeline, video interviews with traditional musicians, cultural stories, animated instrument explanations, and interactive quizzes, as elaborated below.

- VR integrates multimedia content into cultural and historical themes [30]. The instruments' significance in West Javanese culture can be highlighted through cultural stories, historical timelines, and video interviews with traditional musicians as exhibits in a virtual museum [31]. In addition, UNESCO states that it is also listed on the Representative List of the Intangible Cultural Heritage of Humanity [32], signifying its role in the culture.

- VR offers global accessibility, allowing anyone with internet access and a VR headset to explore cultural heritage from anywhere, which is crucial for preserving culture [33, 34], while I. Bollati and M. Spanevello [35] state that virtual museums act as digital archives, protecting artefacts and their cultural significance for future generations.

Preserving living musical heritage goes beyond digitising instruments' visual aspects. Elements such as timbre, tuning, playing technique, oral explanation, ensemble relationships, and social or ceremonial context are integral to transmission. Research on audio in immersive cultural storytelling demonstrates that sound contributes to spatial orientation, emotion, narrative coherence, and meaning, rather

than serving merely as decorative accompaniment [36]. UNESCO's work on living heritage and education further emphasises the importance of transmission through communities and educational practice¹. Therefore, EduLaras should be regarded as a complement to teachers, musicians, and situated practice, rather than a substitute. The perceived authenticity and cultural appropriateness of its representations should remain subjects of empirical investigation.

Unified Theory of Acceptance and Use of Technology (UTAUT)

In UTAUT, performance expectancy, effort expectancy, and social influence affect behavioural intentions in using technology, while behavioural intentions and facilitating conditions determine technology utilisation.

In employing VR-based museums for Indonesian traditional music learning, four factors are critical: Performance Expectancy (PE), teachers' expected value of EduLaras for instrument demonstration, access, and cultural inquiry; Effort Expectancy (EE), perceived ease of operating the headset, controllers, and navigation; Social Influence (SI), perceived endorsement from colleagues, leaders, students, and cultural practitioners; and Facilitating Conditions (FC), perceived availability of devices, training, technical support, and institutional arrangements. These constructs are defined operationally in the Introduction; here they are used only to frame the pilot's descriptive analysis, not as latent predictors.

In the original UTAUT, PE, EE, and SI predict behavioural intention. In contrast, behavioural intention and facilitating conditions (FC) contribute to use behaviour [37]. The present pilot study does not replicate this structural model; instead, it retains the 37 items as preliminary indicators of teachers' perceptions and readiness, without administering a dedicated behavioural-intention or actual-use scale. Consequently, UTAUT serves as a sensitising and organising framework to clarify the pilot's role.

Technological Pedagogical and Content Knowledge (TPACK)

TPACK encompasses the integration of technology and pedagogy to create effective educational content [38] and to support effective teaching [39]. It consists of key knowledge domains: Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), and Technological Pedagogical Knowledge (TPK). TPACK continues to evolve, with the work of M. Koehler and P. Mishra [40] providing a comprehensive explanation:

- Content Knowledge (CK): teachers' comprehension of Indonesian traditional music – history, cultural significance, instruments, rhythms, and technique [41].
- Pedagogical Knowledge (PK): teachers' understanding of instructional aims, principles, and strategies suited to VR's immersive qualities [42]. According to P. Tamir², pedagogical knowledge encompasses multiple facets, including education's aims, principles, and objectives.

¹ UNESCO. About living heritage and education. Intangible Cultural Heritage. Accessed February 12, 2026. <https://ich.unesco.org/en/about-01159>

² Tamir P. Subject matter and related pedagogical knowledge in teacher education. *Teaching and Teacher Education*. 1988;4(2):99–110. doi:10.1016/0742-051X(88)90011-X

- Pedagogical Content Knowledge (PCK): synchronising traditional-music content with instructional methods that foster cultural appreciation [43].
- Technological Knowledge (TK): teachers' ability to operate, maintain, and troubleshoot VR tools and curate virtual content.
- Technological Content Knowledge (TCK): understanding how VR can represent musical instruments and sound in ways traditional media cannot [44].
- Technological Pedagogical Knowledge (TPK): integrating VR's immersive features with pedagogical methods such as problem-solving and experiential practice [45].

Critical synthesis and identification of research gap

The reviewed evidence yields four principal conclusions. First, while immersive VR may enhance presence, interest, and access, learning benefits depend on instructional design and cannot be assumed from positive user reactions alone [4, 46]. Second, an audio-centred virtual museum of musical heritage should mediate sound, technique, narrative, and community context, rather than merely reproduce three-dimensional objects [47, 48]. Third, teachers serve as key implementation stakeholders; their initial experiences can reveal discrepancies between prototype operability and classroom feasibility. Previous studies with school educators similarly highlight training, content alignment, technical reliability, and organisational factors as critical implementation considerations.

UTAUT and TPACK should not be merged into an unvalidated causal model. However, research remains limited on how first-time teacher users interpret an audio-centred virtual museum for West Javanese instruments, and how their quantitative responses, open-ended feedback, and observed interactions collectively inform design and study improvements. Addressing this gap is the purpose of the present formative mixed-method pilot.

Methodology

This study introduces the EduLaras Virtual Museum as a prototype designed to examine teachers' initial responses to a virtual reality museum featuring traditional Indonesian musical instruments. Developed using Unity for the Meta Quest headset, the prototype focuses specifically on instruments from West Java. Users can play virtual instruments, listen to audio samples, and access contextual information. Figure 1 below shows a screenshot of the EduLaras Virtual Museum app, which illustrates how West Javanese musical performances are presented through virtual reality learning.



Fig. 1. *Gamelan Degung* instrument learning classroom in the EduLaras Virtual Museum (Source: Screenshot from the EduLaras Virtual Museum app)

We employed an exploratory mixed-methods pilot design to evaluate teachers' initial responses to the EduLaras virtual museum for West Javanese traditional music. UTAUT and TPACK served as sensitising and interpretive frameworks rather than a combined causal model. Quantitative data consisted of 37 five-point UTAUT- and TPACK-related rating items and the standard 10-item SUS, completed by 32 teachers. Qualitative data included the same teachers' responses to five open-ended questions (OEQ). Unstructured observations documented first-use orientation, visible engagement, requests for assistance, and practical questions during the facilitated trial. As no observation checklist or time-sampling protocol was implemented, observations were considered only as contextual evidence. No student outcomes, behavioural-intention scale, actual-use log, or classroom follow-up data were collected.

Usability should be clearly distinguished from acceptance, adoption, and effectiveness. SUS consists of ten alternating positive and negative items and produces a global score ranging from 0 to 100¹, with established interpretive guidelines [49] and validated measurement properties [50]. In this pilot, we administered the SUS immediately after the facilitated EduLaras trial as an independent measure of perceived first-use usability. The SUS was not combined with UTAUT or TPACK items and is not interpreted as evidence of classroom effectiveness, behavioural intention, actual adoption, or long-term usability. The sample included 32 art and culture teachers from primary, junior-high, senior-high, and vocational schools. Participants were purposively recruited through a regional teacher activity as school-based informants who could complete the hands-on trial and provide formative feedback. All participants were adult teachers. Participation was voluntary, and informed consent

¹ Brooke J. SUS: a quick and dirty usability scale. In: Jordan P.W., Thomas B., Weerdmeester B.A., McClelland I.L., eds. *Usability Evaluation in Industry*. London: Taylor & Francis; 1996:189–194.

was obtained from all participants prior to the facilitated trial; participants were informed of the study's purpose, their right to withdraw at any time without penalty, and how their data would be used and reported. The group represented diverse arts-teaching backgrounds, including music, dance, and visual art; some participants also combined school teaching with traditional-music practice. Specialisation and practitioner status were documented only in recruitment and facilitator notes, not through a standardised demographic item, and are therefore treated as contextual characteristics rather than variables for subgroup analysis. Of the participants, 20 were men (62.5%), and 12 were women (37.5%). 16 had taught for less than one year (50.0%), 10 for one to five years (31.3%), three for six to ten years (9.4%), and three for more than ten years (9.4%). School affiliations were concentrated in West Java but extended across multiple districts; the sample was neither probabilistic nor statistically representative. Orientation and session observations indicated that participating teachers were using VR for the first time. However, because no dedicated baseline item captured prior VR experience, this is reported as an observational characteristic rather than a verified moderator.

The Indonesian post-use questionnaire comprised 37 author-adapted items mapped to performance expectancy (PE, 6 items), effort expectancy (EE, 5), social influence (SI, 5), facilitating conditions (FC, 4), content knowledge (CK, 2), pedagogical knowledge (PK, 5), technological knowledge (TK, 2), technological pedagogical knowledge (TPK, 4), technological content knowledge (TCK, 2), and pedagogical content knowledge (PCK, 2). Responses ranged from 1 (strongly disagree) to 5 (strongly agree). These items did not include dedicated behavioural-intention, actual-use, or integrative TPACK measures and were analysed only as preliminary descriptive domains. Perceived first-use usability was assessed separately using the standard 10-item SUS, which included alternating positive and negative wording and a five-point response scale. We administered five OEQs on expected benefits, anticipated barriers, required support, game ideas, and recommendations for EduLaras Virtual Museum.

We examined internal consistency for each author-adapted UTAUT- and TPACK-informed domain and for the standard SUS. We used the coefficients to identify weak or insufficiently represented item groupings before a subsequent larger study; we did not treat them as evidence of factorial, convergent, or discriminant validity. Because the CK, TK, TCK, and PCK domains contained only two items each, we interpreted their coefficients with caution. We therefore assessed item wording and domain coverage as targets for instrument refinement rather than as confirmation of a measure.

Prior to the pilot, challenges in teaching traditional music were identified and EduLaras Virtual Museum was developed with input from music, education, and technology experts. The facilitated session itself included orientation to the headset and controllers; guided exploration of the virtual museum and its interactive instrument features; immediate completion of the 37 rating items, SUS, and five OEQs; and a question-and-answer discussion. Individual guided exposure lasted ap-

proximately 15 minutes. Participants typically entered two virtual classes and spent approximately 4 to 8 minutes in each. Facilitators estimated these durations from notes rather than using an automated log or standardised timing protocol. Facilitators supported initial operation and recorded contextual observations. The session was a formative prototype trial, not a controlled lesson or independent usability test. No comparison group, standardised task sequence, instrumented task-completion time, error count, student participation, or delayed follow-up was included.

We analysed the 32 OEQ sets using qualitative descriptive content analysis. Responses were read repeatedly, divided into meaning units, assigned concise inductive codes, and grouped within the five prompt areas. We checked categories against the original wording and retained infrequent, contradictory, or negative responses. A theme count denotes the number of teachers whose response contained that category; categories were not mutually exclusive. We used contextual observations and question-and-answer notes only to clarify the trial setting. We did not treat them as interview transcripts, formal focus group data, or evidence of thematic saturation.

We summarised the 37 rating items using participant-level domain means, sample standard deviations, and the percentage of item responses scored 4 or 5. Then, we cross-classified PE and FC means at a descriptive threshold of 4.00 to create four exploratory readiness profiles; these do not represent latent classes. Standard SUS scoring was applied by subtracting 1 from odd-item responses, subtracting even-item responses from 5, summing the ten contributions, and multiplying by 2.5. We reported SUS results as mean, standard deviation, median, interquartile range, range, and internal consistency, with explicit inspection for ceiling clustering. We integrated quantitative, OEQ, and contextual evidence in a joint display to identify convergence, complementarity, and divergence. All claims were limited to this purposive pilot sample.

This study adhered to the British Psychological Society (BPS) Code of Human Research Ethics. Informed consent was obtained from all participants, who were assured that they could withdraw at any time without any consequences. Data collection methods, including surveys, interviews, and observations, ensured the confidentiality and anonymisation of personal information. The study received approval from the Institute for Research and Community Service at Universitas Pendidikan Indonesia (UPI), with measures implemented to minimise risks to participants. Throughout the process, the study emphasised respect for participants, research integrity, and honest reporting.

Results

Participant and data-source characteristics

All 32 complete records were retained. The sample comprised 20 men and 12 women. Teaching experience was predominantly among early-career participants: 16 had taught for less than one year, 10 for one to five years, three for six to ten years, and three for more than ten years. All participants completed the 37 rating items, the 10 SUS items, and the five OEQs. Recruitment and facilitator notes indicated a

range of arts specialisations and some experience as traditional-music practitioners, although these characteristics were not collected as standardised variables. School affiliations contributed contextual variation across school levels and districts; however, the purposive sample was not statistically representative. Contextual first-use observations indicated that high usability ratings occurred during a brief supported initial encounter. Individual exposure lasted approximately 15 minutes and typically included two virtual classes, with 4 to 8 minutes of exploration per class. Teachers generally transitioned from orientation to direct navigation and virtual-instrument manipulation without notable visible difficulty. Teachers frequently showed enthusiasm during this initial, novelty-rich experience. During the question-and-answer discussion, teachers consistently linked the prototype's potential value to limited school access to traditional instruments and the need for art and culture teachers to introduce musical material beyond their primary arts specialisation. These observations and discussion notes were unstructured and were not quantified as behavioural frequencies; they serve only to contextualise the SUS and OEQ findings and are not presented as objective evidence of task performance.

Descriptive patterns in UTAUT- and TPACK-related responses

Table 1 presents descriptive patterns across domains. Within the UTAUT-related domains, PE, SI, and EE demonstrated relatively positive responses, whereas FC exhibited lower and more variable scores. TPACK-related ratings indicated moderate confidence in component domains; however, CK remained psychometrically weak, and four domains included only two items each. Consequently, these results reflect item-pool diagnostics and preliminary response patterns rather than validated latent constructs. In the table, agreement refers to the percentage of item responses scored 4 or 5. Alpha values serve as preliminary diagnostics only; the two-item domains and purposive sample of $n = 32$ limit their stability and interpretability.

Table 1
Descriptive domain results for the teacher pilot ($n = 32$)

Domain	Items	<i>M</i>	<i>SD</i>	Agreement (%)	Pilot α
Performance expectancy (PE)	6	3.94	0.60	68.8	.755
Effort expectancy (EE)	5	3.78	0.68	61.9	.791
Social influence (SI)	5	3.82	0.65	61.9	.733
Facilitating conditions (FC)	4	3.51	0.90	45.3	.873
Content knowledge (CK)	2	3.95	0.57	70.3	.368
Pedagogical knowledge (PK)	5	3.78	0.62	63.1	.759
Technological knowledge (TK)	2	3.88	0.83	70.3	.874
Technological pedagogical knowledge (TPK)	4	3.77	0.67	63.3	.857
Technological content knowledge (TCK)	2	3.78	0.71	62.5	.749
Pedagogical content knowledge (PCK)	2	3.73	0.79	57.8	.808

As shown in Table 1, internal-consistency coefficients across the UTAUT- and TPACK-informed domains ranged from .368 to .874. Except for CK, the coefficients ranged from .733 to .874, indicating moderate to high preliminary consistency. CK was weak ($\alpha = .368$), indicating that its two items did not operate as a coherent preliminary domain. Although TK, TCK, and PCK produced moderate-to-high coefficients, each contained only two indicators; consequently, their content coverage and coefficient stability remain insufficient for construct-level validation. These findings identify item-pool revision priorities and do not validate an integrated UTAUT-TPACK measurement model. The standard SUS produced $\alpha = .938$ and is reported separately with the first-use usability results below.

Item-level analysis further clarified the implementation gap. The EE quick-to-learn item yielded a mean of 4.00 with 68.8% agreement. Perceived social legitimacy was higher, with 84.4% agreeing that the school community considered VR important ($M = 4.34$). In contrast, agreement was lower for administrative support (40.6%, $M = 3.34$), school-provided training (37.5%, $M = 3.38$), access to required resources (46.9%, $M = 3.44$), and adequate infrastructure (37.5%, $M = 3.50$). Technical support was somewhat higher ($M = 3.72$; 59.4%). The elevated rating for expected achievement (PE05, $M = 4.16$) reflects an expectancy judgment rather than evidence of improved student achievement.

Perceived usability during initial use

All 32 participants completed the standard SUS. The mean score was 90.23 ($SD = 9.49$), with a median of 92.50, an interquartile range of 86.25 to 97.50, and a range of 62.50 to 100. Internal consistency following correct reverse scoring was high ($\alpha = .938$). Twenty-one teachers (65.6%) scored at least 90, 27 (84.4%) scored at least 80, and six (18.8%) achieved the maximum score of 100.

This distribution indicates high perceived usability in the facilitated initial-use setting, but also reveals a pronounced ceiling effect. The approximately 15-minute session included orientation, available assistance, and brief exploration of typically two virtual classes. No standardised task completion, instrumented timing, error rates, help requests, or delayed independent use were measured. The SUS results provide evidence of a favourable immediate user experience under supported conditions, but do not establish independent classroom usability, pedagogical effectiveness, or behavioural outcomes.

Exploratory analysis of teachers' readiness configurations

To examine whether perceived value aligned with enabling conditions, we cross-classified PE and FC at the prespecified descriptive threshold of 4.00 (Table 2). Nineteen teachers reached $PE \geq 4.00$. Of these, eight also reached $FC \geq 4.00$, while 11 (57.9% of the high-PE group) were interested but constrained. Three teachers were supported but cautious and 10 were below the threshold on both dimensions.

Table 2

Exploratory readiness profiles based on PE and FC

Profile	Rule	n	%	Interpretive description
Ready adopter	PE $\geq$ 4; FC $\geq$ 4	8	25.0	High perceived value and enabling conditions
Interested but constrained	PE $\geq$ 4; FC < 4	11	34.4	High perceived value; enabling conditions lag
Supported but cautious	PE < 4; FC $\geq$ 4	3	9.4	Enabling conditions present; perceived value cautious
Not-yet-ready	PE < 4; FC < 4	10	31.3	Both dimensions below the descriptive threshold

Summary of open-ended findings

The pilot open-ended question (OEQ) results provided further detail by clarifying the perceived value of EduLaras Virtual Museum and outlining pilot implementation requirements. The most frequently cited benefits related to enhanced learning and understanding (18/32, 56.3%) and increased engagement or perceived modernity (15/32, 46.9%). Additionally, eight teachers (25.0%) highlighted cultural recognition or preservation and improved access or flexibility, while six (18.8%) noted immersion or realism. These categories reflect anticipated pedagogical value rather than directly measured student learning outcomes.

The dominant anticipated barrier in the pilot was resources, access, and cost (23/32, 71.9%), followed by training or adaptation (13/32, 40.6%). Five teachers raised technical reliability or comfort (15.6%), four raised cultural-content or authenticity concerns (12.5%), and one identified weak public interest. Correspondingly, hardware or infrastructure was the most frequent support requirement (24/32, 75.0%), followed by institutional or financial support (14/32, 43.8%), training or human support (13/32, 40.6%), partnerships (5/32, 15.6%), and cultural expertise (3/32, 9.4%).

In the pilot, teachers contributed as formative co-design informants. Their suggestions focused on aural, rhythm, or tuning activities (15/32, 46.9%); performance, simulation, or collaborative experiences (12/32, 37.5%); and adventure, quest, or exploratory structures (8/32, 25.0%). Recommendations emphasised the importance of interactivity or gamification (11/32, 34.4%), improved access or dissemination (8/32, 25.0%), sustained development (8/32, 25.0%), inclusion of additional instruments or content (6/32, 18.8%), and technical or audio-visual refinement (5/32, 15.6%). Specific examples included rhythm-game formats, virtual instrument exploration, ensemble simulation, cultural quests, quizzes, clearer interaction, and enhanced device responsiveness.

To integrate the descriptive ratings, open-ended responses, and contextual observations, Table 3 presents a joint display of the principal findings. It shows how favourable perceptions of first-use usability and pedagogical value coexist with concerns about institutional resources, teacher support, and cultural authenticity. The

integrated inferences remain formative because observations were unstructured and neither classroom adoption nor student learning outcomes were measured.

Table 3
Joint display of descriptive, open-ended, and contextual evidence

Dimension	Descriptive ratings	OEQ/observation evidence	Integrated inference and boundary
First-use usability	SUS $M = 90.23$, $SD = 9.49$; median = 92.50; $\alpha = .938$	Facilitator-estimated exposure was approximately 15 min, typically across two virtual classes (approximately 4-8 min/class); navigation and manipulation were generally manageable, enthusiasm was common, and training/adaptation was still anticipated by 13/32	High immediate usability is plausible within a short, facilitated, novelty-rich trial; ceiling clustering and the absence of timed independent tasks bound inference about classroom use
Pedagogical and cultural value	PE $M = 3.94$; community importance $M = 4.34$ (84.4% agreement)	Learning/understanding: 18/32; engagement: 15/32; cultural recognition: 8/32; contextual comments linked value to scarce instruments and cross-specialism needs; authenticity concerns: 4/32	EduLaras Virtual Museum may scaffold preliminary access and cross-specialism teaching, but these are expectations and legitimacy judgements, not learning outcomes or verified cultural accuracy
Institutional enablement	FC $M = 3.51$; access 46.9%; training 37.5%; infrastructure 37.5%	Resources/access/cost: 23/32; hardware/infrastructure support: 24/32; institutional/financial support: 14/32	An access-substitution paradox emerged: VR may widen access to scarce instruments while requiring new digital infrastructure; no actual classroom adoption was measured
Pedagogical integration	TPK $M = 3.77$; TCK $M = 3.78$; PCK $M = 3.73$	Training/human support: 13/32; simulation/performance ideas: 12/32; cultural expertise: 3/32; varied arts specialisations and practitioner roles were contextual, not standardised variables	Cross-specialism potential is plausible, but basic confidence did not establish validated VR-specific lesson-design competence and subgroup effects cannot be inferred
Formative co-design	No behavioural-intention, actual-use, or student-outcome measure	Aural/rhythm ideas: 15/32; interactivity/gamification: 11/32; access/dissemination: 8/32; sustained development: 8/32	Suggestions define prototype hypotheses and implementation priorities, not tested solutions

Divergent and negative cases

The data did not indicate uniformly positive outcomes. Ten teachers were categorised as not-yet-ready, while three were supported but remained cautious. The SUS scores ranged as low as 62.50, despite a high mean. Six teachers reported perfect SUS scores, and 21 scored at least 90, suggesting a pronounced ceiling effect. One teacher anticipated no barriers, whereas another cited community disinterest. Five teachers expected technical reliability or comfort issues, and four expressed

concerns regarding authenticity. These negative and discrepant cases demonstrate that a high SUS mean does not necessarily reflect uniform readiness or confirmed classroom feasibility.

Discussion

High initial usability accompanied by conditional implementation readiness

The primary finding is not the high SUS score alone, but its coexistence with weaker implementation conditions. EduLaras Virtual Museum achieved a mean SUS score of 90.23. Performance expectancy (PE, $M = 3.94$), social influence (SI, $M = 3.82$), and effort expectancy (EE, $M = 3.78$) all exceeded facilitating conditions (FC, $M = 3.51$), which also exhibited the greatest dispersion ($SD = 0.90$). This pilot study therefore identified a gap between usability and readiness for implementation. At the interactional level, teachers generally navigated and manipulated the prototype during an approximately 15-minute supported initial encounter. However, at the organisational and material level, access, training, infrastructure, and administrative support remained uncertain. UTAUT distinguishes perceived value, effort, social influence, and facilitating conditions theoretically [11–13, 51]; the present data illustrate why these dimensions must remain distinct from usability. A system may be enjoyable and easy to learn in a workshop setting without being ready for routine use as a school resource.

Item-level contrasts further clarify this gap. School-community importance reached a mean of 4.34 with 84.4% agreement, whereas administrative support reached a mean of 3.34 with 40.6% agreement, and school-provided training reached a mean of 3.38 with 37.5% agreement. Consequently, community importance exceeded administrative support by 43.8 percentage points and training by 46.9 points; the corresponding mean differences were 1.00 and 0.97 on a five-point scale. Qualitative evidence was consistent: 23 of 32 teachers (71.9%) anticipated challenges related to resources, access, and cost, surpassing any benefit category, including learning and understanding (18/32, 56.3%). These findings indicate conditional or symbolic acceptance: EduLaras Virtual Museum is perceived as culturally legitimate and easy to use, yet its institutional integration into classroom practice remains unresolved.

This convergence highlights an access-substitution paradox. Teachers valued EduLaras Virtual Museum in part because many schools lacked complete collections of West Javanese musical instruments. However, implementing the virtual alternative would require headsets, compatible devices, technical support, scheduling, and institutional financing. Virtual access may therefore broaden representational access while shifting material inequality from musical instrument provision to digital infrastructure. EduLaras Virtual Museum should thus be evaluated as part of a comprehensive school implementation package rather than as standalone software.

Contextual observations also indicate a cross-specialism function. Art and culture teachers may be primarily trained in music, dance, or visual art, yet are still required to introduce musical heritage. For those teaching outside their original arts

specialisation, a virtual museum may serve as an orientation and lesson-preparation scaffold. Participants' support for traditional music practice experience further suggests professional and cultural legitimacy. However, because we did not collect specialisation and practitioner status through standardised demographic items, these interpretations remain propositions for future investigation rather than demonstrated subgroup effects.

Readiness exhibited a configurational pattern rather than a uniform distribution

The four descriptive profiles further support this interpretation by demonstrating that readiness does not exist along a single continuum. Nineteen teachers achieved PE scores of 4.00 or higher; however, only eight of these also attained FC scores of 4.00 or higher. The remaining eleven teachers (57.9% of the high-PE group) exhibited interest but faced constraints. Three teachers were supported but remained cautious, and ten fell below the threshold on both dimensions. Neither perceived value nor facilitating conditions alone proved sufficient: high PE without FC indicated unrealised interest, whereas FC without high PE reflected capacity without corresponding pedagogical conviction.

These profiles serve as transparent heuristics rather than validated categories, yet they reveal distinct implementation challenges that are obscured by aggregate measures. Interested-but-constrained teachers primarily require access to devices, technical support, scheduling accommodations, and institutional approval. Supported-but-cautious teachers need curriculum alignment and compelling evidence of added pedagogical value. Not-yet-ready teachers need both an evidence-based rationale and enabling support, whereas the ready group is best suited for monitored classroom trials. Consequently, a uniform training programme would be inefficient; support strategies should be tailored to the specific configuration of perceived value and capacity.

High perceived usability did not guarantee feasible classroom implementation

SUS and effort-expectancy measures reflect related but distinct judgments. The SUS mean score of 90.23 and the quick-to-learn item ($M = 4.00$; 68.8% agreement) indicate a favourable immediate interaction with EduLaras Virtual Museum. This outcome is plausible given the observed conditions: approximately 15 minutes of guided exposure typically enabled participants to enter two virtual classes and spend 4 to 8 minutes in each, after which direct navigation and instrument manipulation were generally manageable. However, 13 teachers (40.6%) anticipated the need for training or adaptation, and 24 (75.0%) requested additional hardware or infrastructure. These findings are not contradictory. The SUS provides a global post-use appraisal of the system. In contrast, classroom implementation also requires device preparation, troubleshooting, headset rotation, aligning activities with lesson objectives, learner supervision, and managing comfort and time.

This distinction aligns with teacher-focused virtual reality research, which demonstrates that promising interfaces can coexist with challenges related to equipment, navigation, professional development, and classroom organisation [52,

53]. Visible excitement during initial encounters may indicate genuine ease of use, but it can also result from novelty, facilitator presence, or the appeal of game-like interaction. Participants received orientation and assistance; task order was not standardised, and variables such as task time, errors, help requests, discomfort, and delayed retention were not measured. Additionally, 21 SUS scores were at least 90 and six were perfect, suggesting that ceiling effects may reflect favourable interaction, novelty, acquiescence, facilitator influence, or a combination of these factors. Future evaluations should distinguish interface usability through standardised tasks and SUS, instructional usability through lesson preparation and classroom orchestration, and sustained feasibility through repeated independent use and maintenance.

TPACK patterns indicated an integration issue rather than a skills deficit

The TPACK-related pattern provides further insight into conditional readiness. Component-domain means were moderately positive: CK = 3.95, PK = 3.78, and TK = 3.88. The intersecting domains were TPK = 3.77, TCK = 3.78, and PCK = 3.73. These minor descriptive differences should not be interpreted as statistically significant gaps. However, they suggest that a positive initial experience does not necessarily demonstrate a teacher's ability to design culturally accurate learning sequences, manage device rotation, scaffold musical listening or performance, or assess learning. The TPACK framework helps examine how teachers integrate technology, pedagogy, and content in teaching [15]. Measurement diagnostics (see Results and Limitations) preclude construct-level claims; TPACK should be regarded as a diagnostic framework rather than a latent causal score.

Cultural legitimacy served as both an affordance and a constraint on quality

The cultural evidence adds a domain-specific layer that generic usability and technology-acceptance measures would miss. Eight teachers (25.0%) associated EduLaras Virtual Museum with cultural recognition or preservation, and 84.4% agreed that VR was important to the school community. One participant described the experience as a way to connect more closely with their culture, while another emphasised that the actual instruments should accompany VR. This suggests that local content contributes to legitimacy: EduLaras Virtual Museum was evaluated not only as a device but as a possible bridge to West Javanese musical heritage. For schools without complete instrument collections, the prototype may support preliminary listening, identification, comparison, and contextual exploration. These are perceived possibilities, not measured cultural-learning outcomes.

Cultural relevance does not equate to cultural accuracy. Four teachers expressed concerns regarding content or authenticity, and three highlighted the need for cultural expertise. The local specificity that enhances EduLaras's appeal also creates a responsibility to represent timbre, tuning, technique, terminology, ensemble relationships, and social context accurately. In an audio-focused museum, sound is a core component of the knowledge being conveyed, rather than a decorative element [51]. UNESCO's living-heritage perspective similarly prioritises community-based

transmission and practice¹. Consequently, EduLaras Virtual Museum should be positioned as a cultural-pedagogical bridge rather than a digital replacement for instruments, artists, teachers, or situated performance. Cultural practitioners should be involved in decisions regarding recordings, narratives, classifications, and simplification.

Teachers' feedback shifted the evaluation process towards formative co-design

Open-ended responses extended beyond general approval. Teachers suggested aural, rhythm, or tuning activities (15 teachers, 46.9%); performance, simulation, or collaboration (12 teachers, 37.5%); and adventure, quest, or exploratory structures (8 teachers, 25.0%). Recommendations focused on interactivity or gamification (11/32), access or dissemination (8/32), sustained development (8/32), additional instruments or content (6/32), and technical or audio-visual refinement (5/32). These suggestions position teachers as formative co-design informants who that extend beyond the scope of a standard usability evaluation. These categories can be operationalised as testable requirements. Rhythm and tuning suggestions indicate the need for meaningful listening, discrimination, timing, and tuning tasks rather than generic rewards. Simulation and collaboration recommendations suggest ensemble roles, turn-taking, and designs that retain value with limited headset availability. Quest structures can support exploration and cultural narrative while maintaining musical objectives. Access concerns highlight the importance of offline or low-bandwidth options, short modular sessions, device-sharing protocols, and a non-VR companion mode. Requests for simplicity, responsiveness, sound quality, and additional content indicate the necessity for iterative usability and cultural review. These remain design hypotheses that require validation through task-based, classroom, and cultural studies.

Negative cases and alternative explanations temper the overall positive pattern observed

A rigorous interpretation must also consider evidence that challenges a straightforward innovation-success narrative. Ten teachers were not yet ready to adopt the innovation, three were supported but remained cautious, and the lowest SUS score was 62.50. Five sets of OEQ responses highlighted concerns regarding technical reliability or user comfort, four addressed issues of cultural authenticity, and one participant anticipated community disinterest. While six teachers achieved perfect SUS scores, such ratings may indicate a measurement limitation by reducing differentiation among responses. Addressing equipment limitations alone would not resolve all concerns; some teachers require greater curriculum relevance, clearer learning sequences, or increased confidence in cultural representation.

Several alternative explanations remain plausible. Immediate ratings may have been inflated by novelty effects, facilitator presence, social desirability bias, acquiescence, or contrast with familiar media; the negative skew and ceiling clustering of SUS scores support this interpretation. In contrast, low FC may reflect general

¹ UNESCO. About living heritage and education. Intangible Cultural Heritage. Accessed February 12, 2026. <https://ich.unesco.org/en/about-01159>

school-resource constraints rather than barriers specific to EduLaras Virtual Museum. Half of the sample had less than one year of teaching experience, which could influence enthusiasm, institutional knowledge, or access to decision-making. The study did not measure age, prior formal VR experience, school resources, or voluntariness with sufficient rigor to test these alternative explanations. Same-session self-report introduces common-method bias, and unstructured observation does not establish behavioural frequency or independent performance. Consequently, these findings should be regarded as formative evidence from a guided initial encounter rather than stable estimates of future behaviour.

Scientific contribution and propositions for future research

The primary scientific contribution is empirically distinguishing three levels previously conflated in the original analysis, rather than confirming a combined UTAUT-TPACK adoption model or asserting that a high SUS score predicts use. At the interactional level, perceived first-use usability was high. At the pedagogical level, teachers had to translate VR operation into activities that were both culturally and instructionally coherent. At the organisational level, disparities persisted in devices, training, infrastructure, technical support, and administrative commitment. Cultural authenticity intersects all three levels, influencing perceived value, instructional quality, and implementation legitimacy. Identifying this multilevel usability-readiness gap offers a more precise contribution than simply relabelling mixed indicators as behavioural intention, technology use, or effectiveness. This positions readiness for a culturally situated virtual museum as a multilevel condition rather than an individual acceptance state.

The findings yield three propositions for subsequent empirical testing. First, facilitated exposure may enhance perceived usability and perceived value more rapidly than facilitating conditions, as the former can change through direct experience, whereas the latter rely on institutional capacity. Second, strong cultural or social legitimacy without material and administrative support may lead to symbolic acceptance rather than implementation. Third, the progression from perceived usability to classroom use likely depends on facilitating conditions, VR-specific pedagogical integration, and confidence in cultural accuracy. These propositions draw on UTAUT, TPACK, SUS, and qualitative evidence, but do not represent causal results from this pilot study.

A larger follow-up study should proceed in stages rather than beginning with a complex structural model. First, revise the 37-item pool, strengthen the two-item domains, and add dedicated behavioural-intention and continued-use measures without merging them with the SUS. Second, repeat usability testing using standardised tasks, including measures of completion, errors, assistance, comfort, and delayed independent use. Third, small-scale classroom feasibility trials should document lesson plans, device rotation, duration, technical incidents, student participation, and repeated use. Fourth, measure independent student outcomes only if effectiveness when claimed. A subsequent confirmatory survey should employ validated constructs, broader sampling, and an a priori power analysis. The current pilot

study ($n = 32$) reduces conceptual, measurement, cultural, and implementation risks before scaling up.

Synthesis of findings across research questions

Collectively, the evidence addresses the three research questions at distinct analytical levels. For RQ1, teachers reported high perceived first-use usability; relatively positive perceptions of PE, EE, and SI; weaker FC; and only preliminary confidence related to TPACK. The readiness profiles indicated that usability and perceived value alone did not ensure enabling conditions. For RQ2, OEQ responses and contextual evidence elucidated the observed patterns through anticipated learning and engagement benefits, resource and training barriers, cultural opportunities, authenticity concerns, and specific co-design priorities. For RQ3, the findings supported a sequential approach: refine the interface and cultural content, develop a feasible school implementation package, revise the measurement instrument, conduct independent usability and classroom-use testing, and evaluate learning outcomes in a separate controlled phase. The resulting conclusion is more focused and robust than a general adoption claim: EduLaras Virtual Museum was rated highly usable during facilitated first use, but sustainable integration remained contingent on institutional, pedagogical, technical, and cultural alignment.

Limitations

This pilot study has six primary limitations. First, the 32 teachers recruited through purposive sampling were concentrated in West Java and unevenly distributed across regions and experience levels, which limits statistical representation of the provincial teacher population. Second, SUS scores demonstrated pronounced ceiling effects, and no standardised data were collected regarding task performance, error rates, assistance required, discomfort, or continued use after a time interval. Third, the distribution of statement items across TPACK domains was inconsistent, preventing construct validation. Fourth, responses to open-ended questions varied in depth, and observations lacked structure; neither supports claims regarding data saturation or behavioural frequency. Fifth, participants exhibited diverse competency backgrounds within the Arts and Culture subject area. Sixth, self-report ratings collected in the same session as the trial introduce common-method bias, and immediate responses may reflect novelty, facilitator presence, or social-desirability effects rather than stable judgments; the facilitated nature of the session similarly limits inference to independent, unsupported use. Consequently, the findings reflect perceived usefulness upon initial use, formative perceptions, conditional readiness, and development priorities, but do not establish effectiveness, causal relationships, or sustained adoption.

Conclusion

For RQ1, teachers reported high perceived first-use usability and relatively positive PE, EE, and SI, but weaker FC – 11 of 19 teachers with $PE \geq 4.00$ still fell below $FC = 4.00$ – and instrument diagnostics did not support construct-level claims. The pilot thus distinguishes a promising guided introduction from readiness for inde-

pendent classroom use. For RQ2, teachers viewed EduLaras as a valuable learning and engagement tool, especially where instrument collections or specialist coverage are lacking, but cited device access, cost, infrastructure, training, and cultural accuracy as key barriers. Suggestions for aural, rhythm, simulation, and quest activities, alongside authenticity concerns, point to a need for cultural governance in design. For RQ3, the evidence supports the staged refinement process detailed in Practical Implications: culturally reviewed interface improvements, a school implementation package, a revised item pool, and independent usability and classroom-feasibility testing before assessing learning outcomes.

Overall, the evidence supports the claim in the title: a virtual museum can serve as a tool for studying traditional Indonesian musical instruments, but its educational value depends on more than immersion or novelty. EduLaras is best understood as an introductory cultural-pedagogical bridge that prepares, rather than replaces, engagement with real instruments, teachers, and cultural practice. The usability-readiness gap and access-substitution paradox indicate that success depends on four interdependent conditions; usable interaction, pedagogical orchestration, institutional capacity, and cultural authenticity – since readiness reflects the ecosystem’s capacity to translate virtual access into feasible, culturally responsible learning, not mere acceptance of a device.

Practical Implications

The immediate priority is to develop a practical school implementation package that addresses the access-substitution paradox identified in this pilot, rather than focusing solely on hardware provision. EduLaras Virtual Museum development should include: (1) concise onboarding, user guidance, and troubleshooting; (2) curriculum-aligned lesson modules and rotation plans for limited headsets; (3) offline or low-bandwidth functionality where feasible; (4) culturally reviewed audio, visuals, terminology, and narratives co-developed with teachers, musicians, artists, and cultural experts; (5) iterative, task-based testing of aural, rhythm, instrument-simulation, collaborative, and quest activities; and (6) school-level planning for scheduling, technical support, maintenance, and financing. EduLaras Virtual Museum is intended to complement, not replace, physical instruments, teachers, musicians, and local cultural practices. The high SUS score supports advancing to independent usability and small-scale classroom feasibility testing. However, the FC and OEQ findings highlight the institutional, pedagogical, technical, and cultural conditions that must be addressed before scaling up.

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