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# Comparative Effects of iPad and Music Glove Technologies on Learning Outcomes and Usability in Elementary Music Education

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## Abstract

This study uses a mixed-methods approach to investigate the learning outcomes, student experiences, and concentration-related behaviour patterns of two classes of elementary school music students ($N = 42$). It compares the academic performance of students using an established music technology, the iPad, with those using an experimental technology, a wearable Music Glove. The results show significant improvements in musical knowledge scores for both the iPad ($W = 1$, $p < .001$) and Music Glove ($W = 28.5$, $p = .043$) groups, with the iPad group demonstrating greater improvement ($d = 1.83$ vs $d = .48$). A Mann-Whitney U test confirmed a significant difference in score improvements between the two groups ($p < .01$). Based on these findings, we propose the Technology Engagement and Adoption for Concentration and Habituation (TEACH) model, an enhancement of the original Technology Acceptance Model (TAM). The TEACH model incorporates additional constructs such as the adaptation curve, engagement, immersion, and prior experience, providing a more comprehensive framework for understanding the relationship between perceived ease of use, actual use, and learning outcomes in technology-enhanced music education. Full details of this study are available in the primary author's doctoral dissertation.



## 1 Introduction

In this study, we aimed to gain a deeper understanding of how established and experimental music technologies affect children's musical academic performance, user experience, and concentration-related behavior. To achieve this, we employed a mixed-method approach, incorporating both quantitative and qualitative data. The quantitative data were derived from three sources: (1) a student musical knowledge assessment to measure learning performance, (2) a user experience survey to gauge students' perceived ease of use of their assigned devices, and (3) qualitative video analysis to assess concentration-related behaviour.
The study involved two groups of students using either an iPad or the Music Glove, a wearable device that produces musical sounds when its sensors are touched. Both devices were used over a six-week period. Our research was guided by the following questions:

- RQ1. What is the difference in musical knowledge before and after using the Music Glove between the two music classes?
- RQ2. How do students rate the perceived ease of use before and after using the iPad or the Music Glove?
- RQ3. What are the differences in concentration-related behaviour patterns while using the iPad or Music Glove in the two music classes?

To address these questions, we utilized the original Technology Acceptance Model (TAM) [19] as our theoretical framework, focusing specifically on the perceived ease of use construct to measure children's ease of use with the technologies. This construct was particularly relevant to understanding the students' ratings of perceived ease of use (RQ2) and concentrated behaviour patterns (RQ3) while using the iPad or Music Glove in their music classes. By examining TAM in relation to our research questions, we aim to expand the original TAM framework with additional constructs to better explain music technology use in music education.

## 1.1 Technology Integration in the Music Classroom

Technology is pervasive in current society, and in recent years, music classrooms have seen significant technological integration. Such integrations involve music students and teachers using innovative devices to encourage hands-on interaction and touch-based feedback as part of the learning process. The most well-known of these devices is the iPad, a tablet computer made by Apple.

[1,2,3,4] provide promising evidence regarding the efficacy of iPads in improving children's educational outcomes in classrooms. Specifically, [4] found children exhibiting appropriate classroom behaviours, remaining highly motivated during lessons, and maintaining focus for extended periods while using the iPad. Similarly, [5] found that students stayed on task longer, preferring iPads over traditional notebooks, and were more engaged with classroom material. Further research has explored the use of iPads in diverse educational environments. [6] studied a Finnish music teacher's use of iPads finding positive practical applications to enhance teaching. For instance, [6] report that the iPad was engaging for the teaching and student to use, and helped the teacher manage their teaching efficiently. Similarly, [7] demonstrated the iPad's effectiveness in developing and improving musical skills among Year 5 primary students. In addition, [8] investigated the use of GarageBand on iPads in an Indigenous Australian school, finding that the technology made music composition more accessible and engaging.

In comparison, other tactile technologies (such as music gloves, e.g., [9]), offer alternative methods for music education. While innovative technologies such as music gloves can also engage students, there is limited research exploring their feasibility and impact on student behaviour in comparison to iPads.

## 1.2 The Music Glove

The Music Glove is a musical MIDI controller designed with touch sensors embedded in a glove that fits on the user's hand (see Figure 1). The touch sensors are activated using the fingers of the opposite hand. The organization of the sensors is intended to facilitate the teaching of the musical scale, intervals, and chord structures, particularly when both the teacher and students are wearing the glove. This approach aims to leverage the Kodály method, emphasizing the use of hand signals during singing lessons.

The touch sensors on the Music Glove are arranged in two rows across the fingertips and thumb. The index finger to the little finger includes sensors mapped to the notes C, D, E, and F, while the thumb contains sensors for A and B. The semitones E-F and B-C are mapped between the ring finger and little finger, and between the thumb and index finger, respectively. These mappings can be customized by the user. The capacitive touch sensors measure the velocity of the push, touch, or stroke, influencing the volume of the sound produced. This setup allows for versatile use, enabling the glove to play chords, control musical sequencers, enter text, or even serve as a game controller.

The device integrates multimodality into its design (mainly auditory and kinesthetic touch-based feedback). This concept of using hands as a musical instrument is not new (see e.g., The MiMu Gloves, [11]), however the Music Glove is among the few devices specifically focused on music education. The Music Glove connects to a host device (such as a laptop or personal computer) via Bluetooth or USB to produce musical sounds. When a user touches the glove's sensors, it generates a data signal that is then transmitted to an external device, such as a MIDI device, a PC, or a computer tablet, for details see, e.g., [4, 5]. Figure 1 illustrates the components of the Music Glove: the glove device (10), touch sensors (16), central MIDI electronic unit (18), Bluetooth transmitter (21), Bluetooth receiver (23), and personal computer (25). This innovative approach targets the hands for musical knowledge and instrument development, contributing to the evolving landscape of music education technology. For details see [9, 10].

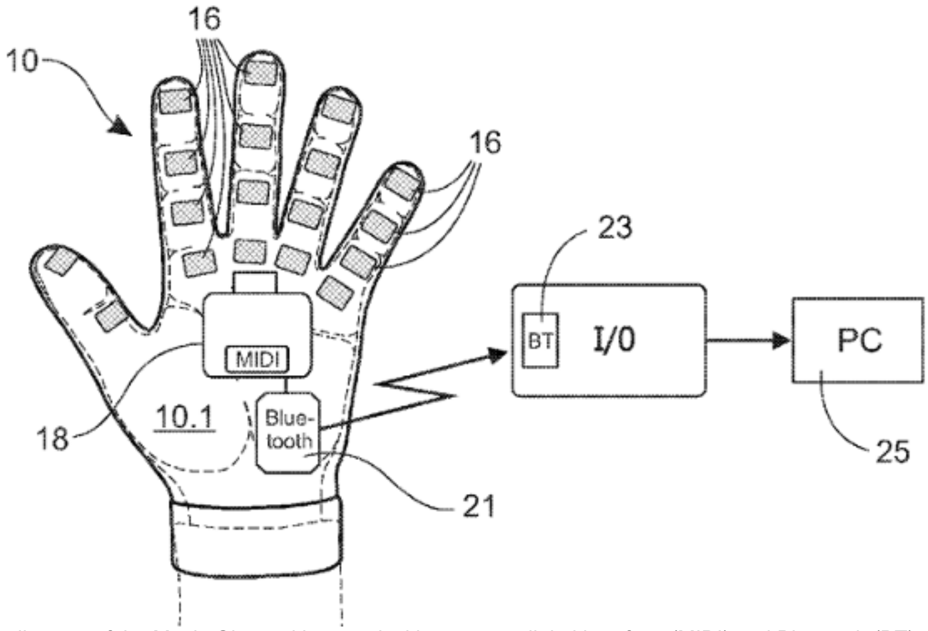


**Figure 1**. A diagram of the Music Glove with a musical instrument digital interface (MIDI) and Bluetooth (BT) connected to a personal computer (PC). The numbers in the diagram refer to the hardware that the Music Glove implements: 10. A Glove device. 16. Touch sensors. 18. Central MIDI electronic unit. 21. Bluetooth transmitting MIDI code. 23. Bluetooth receiver. 25. Personal Computer (host device).

## 1.3 Concentrated Behaviour in the Music Classroom

Concentration is crucial for effective academic learning, with play and experiential learning identified as key strategies to enhance concentration in music education. Concentration is achieved through genuine engagement, where students are cognitively and affectively attuned to acquiring requisite information during lessons. This engagement is essential, as the amount of time and effort spent in the classroom is wasted if students are not learning within their concentration span [12, 13]. Play-based approaches support concentration in the classroom and have been shown to enhance learning and student engagement [14]. For instance, music composition activities in classrooms significantly boost student engagement and concentration, compared to traditional teacher-cantered approaches [15]. In addition, interactive and playful learning environments using technology have been found to significantly improve concentration by stimulating high student interest levels [16].

## 1.4 Technology Acceptance in the Music Classroom

The Theory of Reasoned Action (TRA) is a framework designed to explain why people engage in intentional behavior [17, 18]. An adaptation of this model, the Technology Acceptance Model (TAM), was developed by Fred Davis in 1985 [19] to identify the general reasons behind technology acceptance and elucidate user behavior in deciding to use and interact with technology. [19, 20] emphasized that TAM was created not only to predict user acceptance but also to provide an explanation for it. Consequently, TAM aids researchers and IT professionals in understanding the factors that make a system acceptable or unacceptable to users, thereby guiding improvements and developments.

TAM focuses on two key factors relevant to computer acceptance: perceived usefulness and perceived ease of use [19, 20, 21]. Perceived usefulness refers to the user's belief that using the technology will enhance their task performance, similar to the concept of "affordance" proposed by social psychologist James Gibson [22], which relates to how design features help users achieve their goals. Perceived ease of use pertains to the amount of effort the user expects to invest in using the technology [20]. Behavioral intention in TAM differs slightly from TRA as it incorporates the user's attitude and perceived usefulness of the system, suggesting that positive attitudes can lead to the intention to use the technology [20]. TRA and TAM have been extensively utilized in information systems and social systems research, with further developments such as TAM 2 [23], TAM 3 [24], the Unified Theory of Acceptance and Use of Technology (UTAUT; [25]) and UTAUT2 [26], which elaborate on the emotional and affective dimensions of technology engagement, as well as emphasize the impact of contextual factors.

Recent studies have expanded on TAM's dimensions and constructs, as well as its evolution and application. For instance [21] examined the determinants of perceived ease of use and found that an individual's computer self-efficacy and objective usability impact ease of use perceptions. [27] found that while perceived usefulness consistently affects IT adoption, the impact of perceived ease of use varies depending on the nature of the task, suggesting its importance in specific contexts. [28] applied TAM to electronic collaboration technology and found that perceived usefulness and ease of use positively influenced system usage and student performance.

Collectively, the application of TAM in educational contexts has demonstrated the significance of perceived usefulness and perceived ease of use in predicting and understanding technology acceptance. For instance, [29] conducted a study examining musicians' skills with and attitudes toward technologies in their day-to-day lives, as well as how they engage with technology in learning musical instruments. They developed the Technology Use and Attitudes in Music Learning Survey, which included adaptations of Davis's 1989 scales for perceived usefulness and perceived ease of use of technology. Their results showed a generally positive attitude towards current and future technology use among musicians, supporting TAM in predicting technology use in music learning. [30] investigated the factors influencing student performance using e-learning tools in online and campus-based classrooms. The study found that perceived usefulness and perceived ease of use were significant factors in predicting students' final grades, demonstrating the importance of these constructs in educational technology acceptance.

In the present study, we chose perceived ease of use from the original TAM as the theoretical concept to assess the effort students anticipated needing to interact with technology in the music classroom. This concept was well-suited to provide both theoretical and practical insights relevant to our study's objectives and research questions. We utilized perceived ease of use to analyze the study's findings, capturing the relationship between participants' behavior, learning performance, and their experiences with the assigned technologies.

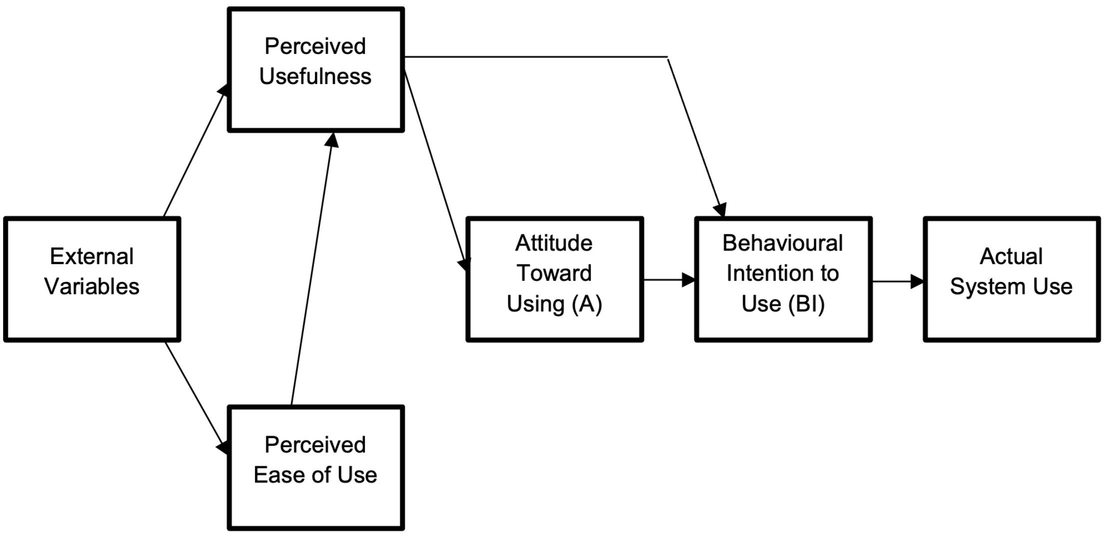


**Figure 2.** Original Technology Acceptance Model (TAM) [19].

## 2 Methodology

We carried out a mixed-method research study in Central Finland, involving two elementary school classes. In one class, students were allocated iPads using a music production app (the Keyboard Touch Instrument app found in GarageBand) for their music lessons. The other class were allocated the Music Glove as their primary device for music lessons.

## 2.1 Participants

The study involved two classes, each consisting of 21 students, totalling 42 participants. These students, aged 8 to 9 years, were enrolled in regular music classes at Jyväskylän Normaalikoulu in Central Finland. Their average age was 8.3 years (SD = 0.5). To ensure the anonymity of the students, each child was allocated a number from #1 to #21 within their respective classes, allowing consistent identification throughout the data collection processes. Concurrent mixed-method sampling [31] was chosen as it aligned with the needs of both the quantitative and qualitative aspects of the study.

## 2.2 Classroom Technology: iPad and Music Glove

The iPad is a tablet with a multitouch screen interface, operating on the iOS platform. It has the capacity to function as a versatile platform for running various applications. Furthermore, we connected the Music Glove to an iPad via USB, with the iPad serving as the host device.

## 2.3 Familiarization with the Music Glove Device

We conducted two familiarization sessions before giving the students the pre-study knowledge test and the Week 1 user experience survey. These sessions served two purposes: (a) allowing the children to learn and experience the equipment before the actual study began and (b) helping the children and researchers get to know each other. This is crucial when conducting research with children as it builds trust and encourages them to express themselves as they normally would [32].

## 2.4 Learning Performance: Student Musical Knowledge Assessment

Both classes of students participated in a musical knowledge assessment as the study began (pre-), and at its conclusion (post-). These pre- and post-tests were used to evaluate the students' retention of musical knowledge and their learning progress before and after utilizing their allocated technologies.

## 2.5 User Experience Survey: Perceived Ease of Use

To assess how the two groups of students rated their ease of use about using their respective technologies during their music class, the students were asked to complete a subjective experience survey before and after using either their allocated iPad or Music Glove. The survey applied a Likert-type scale, which was visually represented in the form of thumb pictures. We conducted a reliability test of the survey during the familiarization sessions. We found no inconsistencies in their responses to the user experience survey after the familiarization session, indicating preliminary validity.

## 2.6 Video Analysis: Student Concentrated Behavior

To examine variations in students' behavior associated with their concentration levels while using the two music technologies, we carried out a qualitative analysis of video recordings capturing students engaged with their allocated devices in the classroom. The two researchers selected lessons from Weeks 1, 3, and 6 for video analysis, covering the beginning, middle, and end of the study. They used a three-phased coding process to analyze the video recordings. After the three-phased coding process and independent analysis, they agreed on two categories to analyze student concentrated behavior: off-task behavior and on-task behavior.

## 2.7 Learning Outcomes

As previous literature suggests [33], when introducing technology in the classroom, the pedagogical practices, context, and purpose defined are significant to the potential effect any technology will have on students. Therefore, in the current study, the teacher supervised the integration of both technologies (iPad and the Music Gove) within both classes.

# 3 Results

## 3.1 Student Musical Knowledge Assessment

All students in both classes completed a Musical Knowledge Assessment. This test served as a baseline measurement of their understanding of the musical syllabus before they started using the devices. After using the technologies, the same test was given again to see if the use of these technologies had an impact on their musical knowledge.

We used Pearson's correlation coefficient to analyze the relationship between the group that used only iPads for music learning (21 students) and the group that used the Music Glove (21 students) for the same purpose. We also compared the test scores at the beginning of the study (Week 1) with the scores at the end (Week 6) of the study. The analysis showed a moderate positive correlation between the initial and final test scores for both groups. The correlation coefficient was .73 for the iPad group and .77 for the Music Glove group.

The results of the knowledge test before and after using the technology are shown in Figure 3. First, we ran two Wilcoxon signed-rank tests to check whether the improvements of the post scores were significant. The MKS improved significantly in both the iPad ($W = 1$, $p < .001$) and Glove ($W = 28.5$, $p = .043$) classes; however, the iPad class improved more than the glove class ($d = 1.83$ vs $d = .48$). Furthermore, we conducted a Mann-Whitney U test to assess whether the improvement in scores between the two groups from before to after the study was significant. The Mann-Whitney U test showed that there was a significant difference in the change of test scores between the students who used iPads (median change = 8) and those who used the Music Glove (median change = 1). The results were statistically significant ($U = 115$, $p = .004$ two-tailed), and the effect size was medium ($d = .77$).

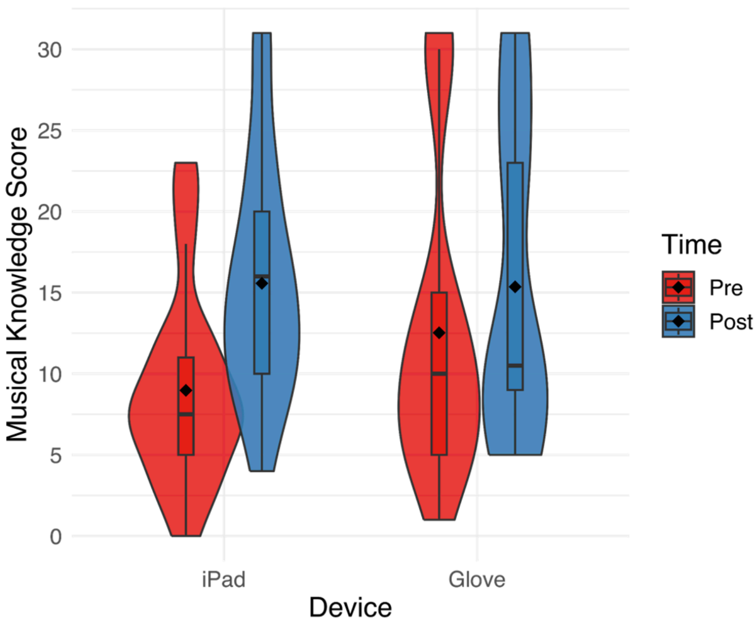


**Figure 3**. Violin plots comparing the pre- and post-learning academic test of knowledge results of the iPad and Music Glove class. The violin plot provides a visual representation of the distribution curve, with interquartile ranges (IQRs) and median values displayed using boxplots, denoted by black horizontal lines. Additionally, mean values are depicted as black rhombi. *Note.* Pre-test presents scores before using allocated technology in the class. Post-test presents scores after using allocated technology in the class. The total test score is out of 31.

## 3.2 Student Perceived Ease of Use

To analyse the change in perceived ease of use responses before and after the students used their allocated technologies, we used two Wilcoxon Signed-ranks tests to examine their perceived ease of use survey responses for both groups.

Before using the iPad at Week 1, the median perceived ease of use rating was 4.00. After using the iPad at Week 6, the median rating decreased to 2.00. Analysis showed a significant change (Z = -2.58, $p$ = .009, $d$ = .80). Before using the Music Glove at Week 1, the median perceived ease of use rating was 4.5. After using the Music Glove at Week 6, the median rating decreased to 1.5. Analysis revealed a significant change with a large effect size (Z = -3.42, $p$ = .001, $d$ = .80).

**TABLE 1.** Descriptive statistics showing the ease of use response ratings during weeks 1, 3 and 6, before and after classes for the iPad and Music Glove classes.

| | Week 1 | | | Week 3 | | | Week 6 | | |
|---|---|---|---|---|---|---|---|---|---|
| **Factor** | **Mean** | **Median** | **SD** | **Mean** | **Median** | **SD** | **Mean** | **Median** | **SD** |
| I think the iPad will be easy to use today | 3.84 | 4.00 | 1.12 | 3.50 | 4.00 | 1.43 | 3.76 | 4.00 | 1.25 |
| Today I found the iPad easy to use | 2.84 | 3.00 | 1.07 | 2.80 | 3.00 | 1.28 | 2.53 | 2.00 | 1.55 |
| I think the glove will be easy to use today | 4.30 | 4.50 | 0.95 | 3.95 | 4.00 | 0.95 | 3.70 | 4.00 | 1.17 |
| Today I found the glove easy to use | 2.80 | 3.00 | 1.06 | 2.35 | 2.00 | 1.82 | 2.10 | 1.50 | 1.21 |

## 3.3 Concentrated Behaviour Observations

Two researchers independently rated and coded the behaviour of the selected students at each observation point. To ensure the accuracy of the collected data, we measured interrater reliability using Cohen's kappa (k). The kappa value was found to be $k$ = .81, indicating a strong agreement between the researchers in their coding categories.

Tables 2 and 3 present the researchers' analysis of the behavior of two representative students in both the iPad-using and Music Glove-using classes. In the iPad-using class, students numbered #7 to #12 were chosen for video analysis, while in the Music Glove-using class, students numbered #3 to #10 were selected for behavior analysis through video recordings.

**TABLE 2.** Total tallies of the researchers' analysis of behaviour in the iPad class.

| Week | Student | Off-Task Behavior | On-Task Behavior |
|---|---|---|---|
| 1 | #7 | 3 | 0 |
| | #12 | 2 | 0 |
| 3 | #7 | 0 | 0 |
| | #12 | 0 | 0 |
| 6 | #7 | 1 | 0 |
| | #12 | 4 | 0 |
| TOTALS: | | 10 | 0 |

*Note. Student indicates the number assigned to students in the class (categorized from #1 to #22). Students numbered #7 and #12 selected for analysis.*

**TABLE 3.** Total tallies of the researchers' analysis of behavior in the Music Glove class.

| Week | Student | Off-Task Behavior | On-Task Behavior |
|---|---|---|---|
| 1 | #3 | 0 | 0 |
| | #10 | 0 | 0 |
| 3 | #3 | 0 | 0 |
| | #10 | 0 | 0 |
| 6 | #3 | 0 | 3 |
| | #10 | 0 | 3 |
| TOTALS: | | 0 | 6 |

*Note. Student indicates the number assigned to students in the class (categorized from #1 to #22). Students numbered #3 and #10 selected for analysis.*

## 4 Discussion

In this study, we found that students using the iPad for music learning showed greater improvement compared to those using the Music Glove, with effect sizes of $d = 1.83$ and $d = 0.48$, respectively. Analysis of changes in perceived ease of use ratings before using both technologies revealed statistically significant results. Qualitative video analysis tentatively suggests that concentration-related behavior was more prominent in the two students who used the Music Glove compared to the two students who used only the iPad.

### 4.1 Impact of Music Glove on Musical Knowledge: Before and After Comparison in Two Classes

As evident from the analysis of post-test results, students who used the iPad displayed greater improvements in their musical knowledge over the 6-week learning period compared to those who used the Music Glove. When we compared the differences in post-test results related to the change between these two groups, we found the difference to be significant ($p = .004$), with a medium effect size ($d = .77$). These results suggest that the use of the iPad contributed more to enhanced learning compared to the Music Glove. These findings align with a previous study that utilized the same data [4] as well as a recent meta-analysis [3].

### 4.2 Student Ease of Use: Comparing iPad and Music Glove Experiences

The results from the perceived ease of use ratings indicate that both the iPad and the Music Glove were perceived as more difficult to use after six weeks of use compared to their initial ratings at Week 1. The study revealed a significant discrepancy between students' anticipated and actual perceived ease of use of their assigned technologies, particularly highlighting the influence of prior experience. Initially, students rated both technologies higher in ease of use before engaging with them, but these ratings decreased consistently across Weeks 1, 3, and 6 after using the devices.

The iPad's initial high ratings were likely due to the students' prior familiarity with the device, which may have led to an overestimation of its ease of use. In contrast, the novelty of the Music Glove, with its hand-sensor technology, contributed to its initial positive reception despite a lack of prior experience. However, the post-use ratings dropped significantly for both technologies, indicating that actual hands-on experience revealed greater effort required than initially anticipated.

This finding underscores the crucial role of prior experience in shaping initial perceptions of new educational technologies, which may not always align with their practical usability in classroom settings.

## 4.3 Student Ease of Use: Comparing iPad and Music Glove Experiences

The differences observed in concentration-related behavior between the two students from each group could be attributed to the students' varying levels of familiarity with the iPad and the Music Glove. It's worth noting that all participants in this study had previous experience using the iPad in their music classes before this experiment began. Therefore, their on-task and off-task behaviors might have been influenced or even caused by their familiarity (with the iPad) or lack of (the Music Glove) with their allocated technology.

Accordingly, the study revealed that students' prior experience with their assigned technology significantly influenced their concentration-related behavior and perceived ease of use. Students familiar with the iPad, having used it in previous music classes, rated it higher in ease of use and exhibited more off-task behavior, likely due to their comfort and familiarity with the device, which encouraged social interaction and play. Conversely, the Music Glove, being a novel technology, was rated lower in ease of use and required more teacher support, leading to higher on-task behavior. This indicates that while familiar technology such as the iPad may foster a more social and interactive learning environment, novel technology (e.g., the Music Glove) demands greater concentration and effort, underscoring the critical role of prior experience in shaping students' engagement and interaction with educational technologies.

## 4.4 The TEACH Model: Enhancing Technology Engagement and Adoption in Educational Settings

The data shows that students observed for concentration-related behavior while using only the iPad engaged in more off-task behavior than those using the Music Glove, suggesting that the former group was not as fully concentrated during the 6-week study. In this context, higher perceived ease of use corresponded to lower interaction effort with the familiar technology (i.e., the iPad), leading to lower levels of concentration-related behavior. On the other hand, the increased concentration-related behavior observed in students using the Music Glove likely stemmed from their heightened effort in interacting with the technology.

Applying the concept of perceived ease of use from TAM [19, 20] illustrates that students had strong expectations about how user-friendly both device interfaces appeared before playing music, but their concentration-related behavior reflected the challenges these technologies presented in practice. As a result of our findings, we consider the limitations of the original version of TAM [19, 20] in the current context due to its over-simplicity. Specifically, the findings from this study suggest that TAM lacks in capturing discrepancies between the initial expectations of the students and their actual experience over time.

First, we propose an adaptation curve construct into the TAM model, reflecting changes in perceived ease of use as users become more familiar with the technology. Despite our study not directly measuring perceived usefulness, the learning outcomes may be regarded as a proxy. The iPad group showed greater improvements in musical knowledge compared to the Music Glove group. Therefore, we propose a direct impact of the technology on learning outcomes and/or performance improvements as a critical aspect of perceived usefulness.

Furthermore, constructs measuring the degree of engagement and immersion as influencing factors for behavioral intention to use the technology are reflected in our findings. This is due to the concentration-related behaviors providing insights into how immersive the technologies were. Students using the Music Glove exhibited higher levels of concentration, which may imply deeper engagement with the task.

Our findings discuss the actual usage of the iPad and Music Glove with specific attention to on-task and off-task behaviors. The iPad group exhibited more off-task behaviors, possibly due to their familiarity with the device leading to less cognitive engagement. An updated model may provide behavioral metrics, such as on-task and off-task behaviors, to provide a wider holistic view of actual system use. Finally, aspects such as prior experience with the technology played a role across the study outcomes. All participants had prior experience with iPads but not with the Music Glove. Therefore, we propose an update explicitly considering prior experience as an external factor affecting both perceived ease of use and perceived usefulness.

Our revised TAM framework, Technology Engagement and Adoption for Concentration and Habituation (TEACH) is shown in Figure 4. The integration and addition of these elements may help address the complexity and variability observed in real-world technology music education adoption scenarios, as reflected in our data. Additional testing and further development of the model will be necessary to ascertain the suitability of this general framework to the issues discussed in this study.

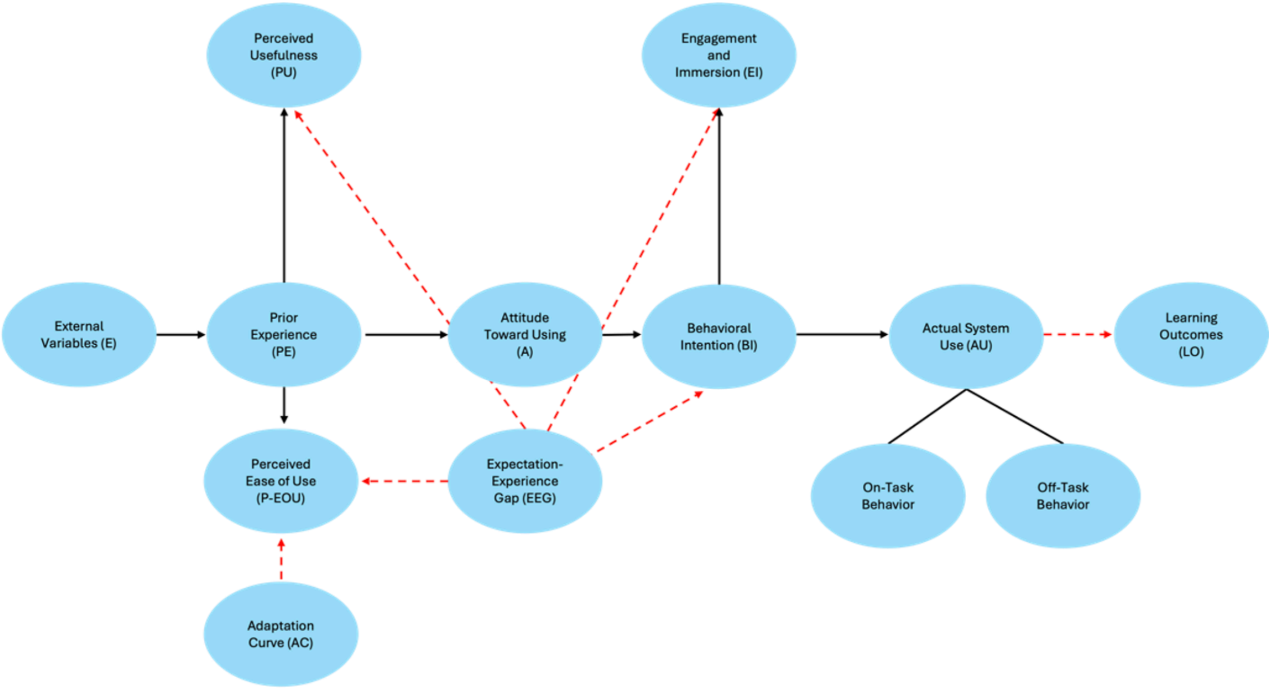


**Figure 4.** The TEACH model illustrates the complex interplay of factors influencing technology acceptance and usage in music education. Key constructs include external variables, prior experience, perceived ease of use (P-EOU), perceived usefulness (PU), behavioral intention to use (BI), actual system use (AU), engagement and immersion (EI), on-task behavior, off-task behavior, adaptation curve (AC), learning outcomes (LO), and the expectation-experience gap (EEG). Solid arrows represent direct effects between constructs, while dashed red arrows indicate influential effects.

Key updated constructs TEACH proposes as an extension to the original TAM [8], include:

- Prior Experience (PE): Users' previous familiarity with the technology, influencing both perceived ease of use (P-EOU) and perceived usefulness (PU).
- Engagement and Immersion (EI): The extent of user engagement and immersion with the technology, affecting BI and influenced by the EEG.
- On-Task Behavior: Use of technology for intended educational purposes.
- Off-Task Behavior: Distracted or irrelevant use of the technology.
- Adaptation Curve (AC): Represents changes in P-EOU as users become more familiar with the technology.
- Learning Outcomes/Performance Improvement (LO): The enhancements in knowledge or skills from using the technology, reinforcing PU.
- Expectation-Experience Gap (EEG): The discrepancy between initial expectations and actual experiences, impacting P-EOU, PU, BI, and EI

## 5 Limitations

The current study provides valuable insights into the use of iPads and experimental hand-based sensor technology in music classrooms, highlighting their strengths in enhancing academic performance and ease of use. However, several limitations warrant consideration. The study did not account for students' prior experience and familiarity with the iPad, which may influence the results. In addition, more sophisticated quantitative measures and a longer study duration may provide a more accurate analysis. The perceived ease of use measurements lacked construct validity, and the qualitative video analysis of concentration-related behavior was limited by a fixed camera angle and a small sample size. Future studies should include stratified sampling, equal familiarity with devices among students, and a consideration of social learning factors. Furthermore, we posit that the Music Glove has potential applications in a variety of fields, including further academic research, special needs education, rehabilitation, and the integration with other technological devices (e.g., virtual reality, [34]).

## 6 Conclusion

In summary, the study revealed several key findings: students who used the iPad showed greater improvement in their learning performance compared to those who used the Music Glove. Initially, both groups rated the perceived ease of use of both technologies highly, but these ratings decreased after six weeks of use. Both groups of students displayed high levels of concentration-related behavior while using their respective devices; however, students using the Music Glove exhibited even higher levels of concentration compared to those using the iPad alone. When considering the relationship between concentration and perceived ease of use based on the Technology Acceptance Model (TAM), we found that both technologies were expected to be easy to use for playing music. However, the iPad required less effort during use compared to the Music Glove, likely due to the students' familiarity with the iPad in their music education. The TEACH model addresses the limitations of the original TAM by incorporating constructs for adaptation curve, engagement, immersion, and prior experience, thereby providing a more comprehensive framework for understanding the nuanced relationship between perceived ease of use, actual use, and learning outcomes in technology-enhanced music education.

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