Evaluating MIDI-based Visual Feedback in Piano Education:
Effects on Performance Accuracy and Dynamic Control

Xiangwei Wang[1]

[1]*Royal Danish Academy of MusicRosenoerns Alle 22, 1970 Frederiksberg C, Denmark*

ABSTRACT
This study examined MIDI-based visual feedback as a supplement to conventional piano instruction. Thirty piano students completed a two-week pre-test-intervention-post-test experiment using measures 1-40 of Chopin's Etude Op. 10 No. 1; 14 received conventional instruction and 16 received the same instruction with MIDI visualization. Performance accuracy was derived from MIDI note events, while Dynamics, Musical Expression, and Overall Performance were assessed through blinded expert ratings. Both groups improved significantly. The MIDI group showed a larger unadjusted gain in accuracy than the control group (26.29 vs. 21.18 percentage points, $p = .033$), but the group effect was not significant after adjustment for baseline accuracy ($p = .286$). Differences in the three expert-rated outcomes were not significant. Students generally valued MIDI visualization for identifying problems and understanding teacher feedback. The findings support MIDI visualization as a complementary, teacher-guided feedback tool rather than a substitute for musical judgment.

Keywords: *Piano Education, MIDI, Visual Feedback, Piano Performance, Technology-enhanced Learning, Dynamic Control.*

1. INTRODUCTION

Piano teaching depends on timely feedback, yet performance is transient and cognitively demanding. Students must coordinate reading, motor control, rhythm, voicing, and expression while monitoring the sound they produce. Teacher comments such as "the accompaniment is too loud" or "the crescendo is unclear" may therefore be understood differently according to a learner's listening experience and self-monitoring ability. A useful supplementary feedback method should help students locate a problem, compare attempts, and connect a teacher's explanation with their own performance without displacing musical listening.

MIDI provides one such possibility by converting digital-piano performance into structured events such as pitch, onset, duration, and velocity. Piano-roll displays can make wrong, missed, or extra notes easier to locate, while velocity visualization can provide a visible reference for relative dynamic tendencies. Because the information remains available after the sound has ended, students can revisit a passage and compare successive attempts. MIDI visualization is therefore treated here as an additional feedback channel rather than an automatic judge of performance.

The present study tests whether existing MIDI visualization tools add measurable value when embedded in otherwise conventional piano teaching. Thirty students studied measures 1-40 of Chopin's Etude Op. 10 No. 1 under either conventional instruction or the same instruction supplemented by MIDI-based visual feedback. Performance accuracy was the primary objective outcome; Dynamics, Musical Expression, and Overall Performance were evaluated through blinded expert ratings, and a short questionnaire captured learner perceptions. Velocity remained part of the instructional display but was not treated as a formal outcome because note-level values in rapid figuration contained unstable matches and local outliers and did not adequately represent overall dynamic handling.

Three questions guided the study: (1) Does adding MIDI-based visual feedback further improve performance accuracy? (2) Does it improve dynamic control or overall performance quality? (3) How do students perceive its usefulness for identifying performance problems and understanding teacher guidance? The broader aim is to examine whether visualization can make selected aspects of feedback more concrete and actionable while leaving artistic interpretation and pedagogical decision-making with the teacher.

2. RELATED WORK

2.1 Digital Feedback in Piano Education

Effective feedback depends on what information is provided, how it is presented, and whether learners can translate it into subsequent action [1]. In piano study, internal auditory, tactile, and motor feedback operates alongside external teacher feedback, while complex aspects such as touch, tone, phrasing, dynamic hierarchy, and style continue to depend heavily on expert judgment. Digital technology does not change this basic role but can preserve selected information for later inspection. Technology-enhanced music learning increasingly integrates digital instruments, visualization, and other feedback tools into instructional design [6]. Visual feedback has also been used in instrumental learning to help students re-examine performance outcomes [7]. The piano is particularly suitable because MIDI events can be recorded directly. Studies by Hamond and colleagues showed that MIDI-based visual information can help teachers and students inspect dynamics, balance, and articulation and increase awareness of performance characteristics [2-4]. Accordingly, the present study treats MIDI visualization as augmented feedback within teacher-led piano instruction.

2.2 MIDI-based Performance Feedback

MIDI records performance events rather than complete acoustic sound. Pitch can support identification of wrong, missed, or extra notes; onset can indicate timing; duration reflects key-hold time; and velocity represents key-strike intensity and can show relative dynamic tendencies. These variables do not represent complete musical performance: velocity, for example, cannot fully capture tone color, touch quality, resonance, or perceived acoustic loudness. In Chopin's Etude Op. 10 No. 1, the piano roll can therefore be used to locate note errors, while velocity provides a supplementary view of continuous figuration and local dynamic relationships. Earlier piano-feedback studies established the feasibility of MIDI- and DAW-based visualization but often relied on small-scale or qualitative designs [2-4], and recent work suggests that different performance indicators may respond differently to visual feedback [5]. This motivates the present controlled pre-test-post-test comparison under conditions kept as close as possible to conventional instruction.

3. METHODOLOGY

3.1 Participants and Experimental Design

Thirty students with prior piano experience participated (age 15-27 years, M = 20.7; mean piano study = 5 years). Participants came from broadly comparable learning backgrounds, and age, years of study, current learning stage, and prior MIDI/DAW experience were recorded. All completed the same pre-test. Grouping considered pre-test performance and years of piano study before random allocation to a control group (n = 14) and a MIDI visual-feedback group (n = 16). The study used a pre-test-intervention-post-test design with the same teacher, repertoire, lesson duration, number of sessions, and learning objectives across groups; feedback mode was the experimental difference.

The control group received verbal explanation, score-based guidance, and teacher demonstration. The experimental group received the same instruction with MIDI visualization added for selected problems; time spent viewing MIDI data was included within, rather than added to, the normal lesson period. The intervention lasted two weeks with four sessions of approximately 40 minutes. Measures 1-40 of Chopin's Etude Op. 10 No. 1 were used throughout teaching and assessment, and none of the participants had previously studied the excerpt systematically. Pre- and post-test performances were recorded simultaneously as MIDI and audio. Participation was voluntary and the resulting recordings, MIDI files, and questionnaire responses were used only for research purposes.

Table 1. Participant Characteristics

Characteristic	Control Group	MIDI Visual Feedback Group	Total
Number of Participants	14	16	30
Mean Age (Years)	20.5	20.9	20.7
Mean Years of Piano Study	5	5	5
Previous MIDI Experience (%)	7.14	6.25	6.67

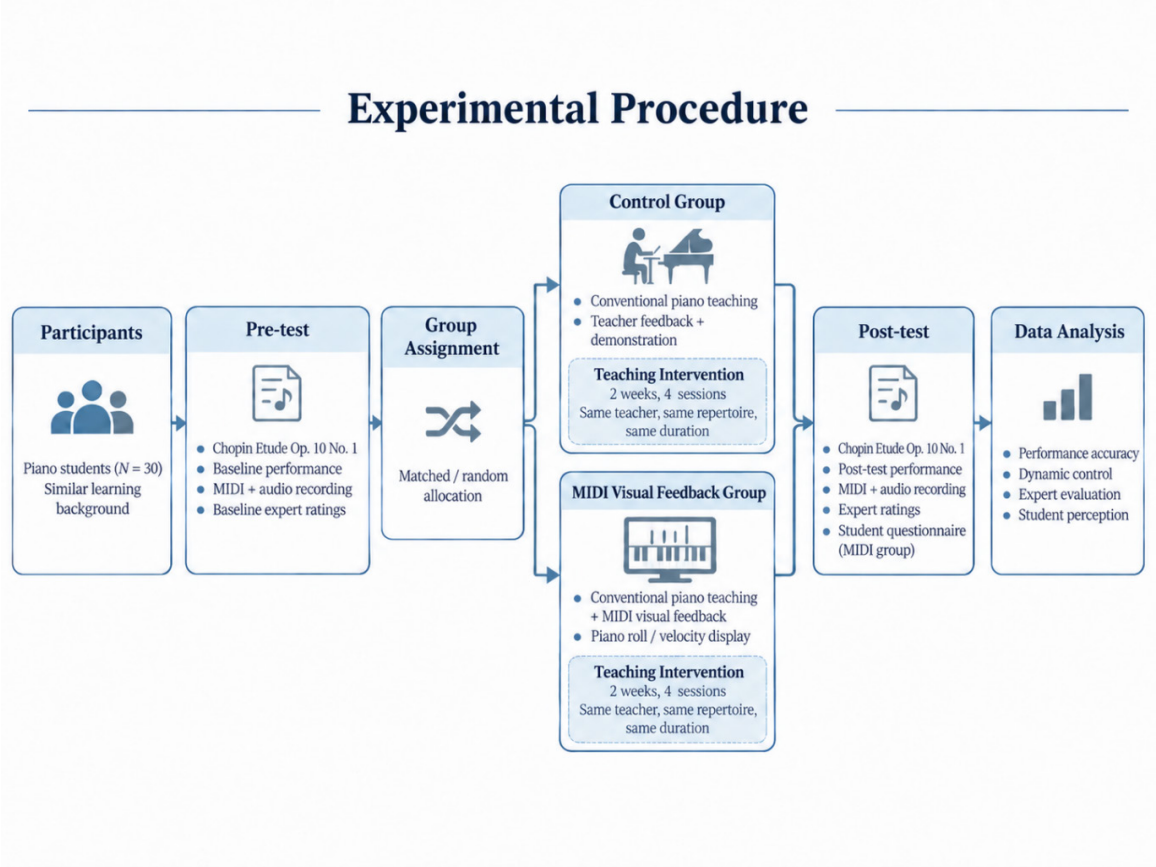


Figure 1 Experimental Procedure.

The procedure comprised pre-test, instructional intervention, and post-test. Before the pre-test, both groups received 30 minutes of standardized independent familiarization with measures 1-40 and no teacher or MIDI feedback. A baseline performance was then recorded. During the intervention, the control group received conventional feedback and the experimental group received the same instruction supplemented by MIDI visualization. The post-test repeated the same excerpt without immediate feedback and used the same recording procedure.

3.2 MIDI-based Visual Feedback Procedure

The setup consisted of a MIDI-capable digital piano, computer, USB-MIDI connection, and DAW or visualization software displaying piano-roll and velocity information. The piano roll was used to compare performed and notated pitches and locate wrong, missed, or extra notes. Note-event positions could also support discussion of obvious rushing, dragging, hesitation, or instability, although microtiming was not analyzed as an outcome.

Velocity visualization was used only as a classroom reference for relative dynamic profiles, local emphasis, and relationships between the hands, not as a formal statistical measure.

When a problem was suitable for visual inspection, students could compare MIDI displays before and after adjustment while the teacher interpreted the musical meaning of the data. The instructional cycle was therefore Perform -> Observe -> Teacher Feedback -> Adjust -> Perform Again. MIDI was used selectively rather than continuously so that attention remained centered on sound and musical goals.

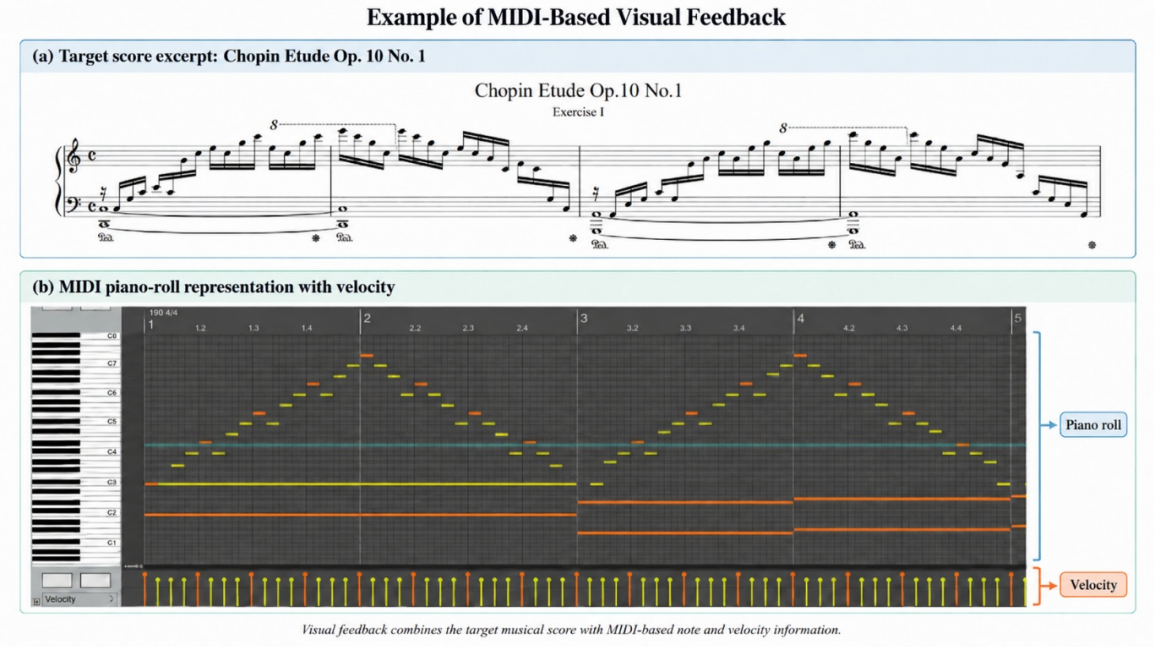


Figure 2 Example of MIDI-Based Visual Feedback.

Figure 2 illustrates the form of feedback with a short excerpt; the formal teaching and assessment range remained measures 1-40. The experimental group used a consistent interface and the teacher limited MIDI use to a small number of clearly defined issues in each lesson to reduce unnecessary visual load.

3.3 Outcome Measures and Data Analysis

Performance accuracy was the primary objective outcome and was calculated by matching each student's MIDI note events to the prescribed score using the same rule set in pre- and post-tests, including wrong, missed, and extra notes. Dynamics, Musical Expression, and Overall Performance were rated independently from anonymized audio recordings by teachers with piano performance or teaching experience. Raters were blinded to group and test stage and scored each dimension on a 1-10 scale. Velocity was not included in the formal quantitative analysis.

After the post-test, the MIDI group completed a brief five-point Likert questionnaire covering problem identification, understanding of teacher feedback, dynamic control, ease of use, performance awareness, and future use. Statistical analysis used paired-samples t tests for within-group pre-post change (Cohen's d_z) and Welch's independent-samples t test on improvement scores (post-test - pre-test) for between-group comparison (Cohen's d), with two-tailed $p < .05$. Accuracy was specified as the primary outcome; the expert-rated dimensions were secondary. Because pre-test accuracy differed between groups, an ANCOVA sensitivity analysis was also conducted with post-test accuracy as the dependent variable and pre-test accuracy and group as predictors.

4. RESULTS AND DISCUSSION

4.1 Performance Outcomes and Interpretation

All 30 participants were included. Accuracy increased from 55.55% (SD = 3.78) to 76.74% (SD = 4.24) in the control group and from 52.65% (SD = 3.16) to 78.94% (SD = 5.98) in the MIDI group.

Both groups improved significantly within group (control: $t(13) = 12.57$, $p < .001$, $d_z = 3.36$; MIDI: $t(15) = 17.17$, $p < .001$, $d_z = 4.29$). On improvement scores, the MIDI group gained 5.11 percentage points more than the control group, $t(27.23) = 2.24$, $p = .033$, $d = 0.82$. However, baseline accuracy was lower in the MIDI group (52.65% vs. 55.55%), $t(25.52) = -2.26$, $p = .032$, $d = -0.84$, and the group effect was no longer significant after ANCOVA adjustment for pre-test accuracy, $t(27) = 1.09$, $p = .286$. The accuracy result should therefore be interpreted as preliminary evidence of a supportive effect rather than a robust demonstration of superiority.

The expert-rated dimensions showed a similar descriptive pattern but no significant between-group advantage. Improvement was 2.07 versus 2.38 for Dynamics (control vs. MIDI), $t(26.28) = 0.88$, $p = .389$, $d = 0.32$; 1.86 versus 2.19 for Musical Expression, $t(26.15) = 1.01$, $p = .324$, $d = 0.37$; and 1.71 versus 2.31 for Overall Performance, $t(23.76) = 1.72$, $p = .098$, $d = 0.64$. All three dimensions improved significantly within each group ($p < .001$), indicating substantial learning under both conditions. The moderate effect size for Overall Performance suggests a trend worth testing in a larger sample, but the present evidence remains inconclusive.

These findings also clarify the pedagogical role of MIDI visualization. Piano-roll information may be especially useful for locating discrete note errors, whereas dynamic and expressive judgments remain less reducible to numerical displays. Velocity can still help a teacher illustrate relative intensity or local emphasis, consistent with prior work on visual feedback [2], but the unstable note-level velocity observed in the rapid figuration of this study supports retaining it as an instructional reference rather than an outcome measure.

Table 2. Between-group Comparison of Improvement Scores

Outcome	Control Improvement Mean (SD)	MIDI Improvement Mean (SD)	Mean Difference	Welch t (df)	p-value	Cohen's d
Accuracy (%)	21.18 (6.31)	26.29 (6.12)	5.11	2.24 (27.23)	.033	0.82
Dynamics	2.07 (1.00)	2.38 (0.89)	0.30	0.88 (26.28)	.389	0.32
Musical Expression	1.86 (0.95)	2.19 (0.83)	0.33	1.01 (26.15)	.324	0.37
Overall Performance	1.71 (1.07)	2.31 (0.79)	0.60	1.72 (23.76)	.098	0.64

4.2 Student Feedback, Pedagogical Implications, and Limitations

Student responses were generally positive. The six-item mean was 4.12/5; ratings were 4.44 for problem identification, 4.44 for understanding teacher feedback, 4.25 for dynamic control, 4.19 for performance awareness, and 4.00 for intention to continue use. Ease of understanding was lower (3.38), suggesting that visual interfaces should remain simple and teacher-guided. Overall, 81.25% selected Agree or Strongly Agree for future use. These perceptions are consistent with earlier findings that digital feedback can focus classroom discussion and increase awareness of performance [3], although positive acceptance should not be mistaken for evidence of superior performance outcomes.

Table 3. Student Perception of MIDI Visual Feedback

Item	Mean	Agree / Strongly Agree (%)
Q1 – Problem Identification	4.44	93.75
Q2 – Understanding Teacher Feedback	4.44	93.75
Q3 – Dynamic Control	4.25	100
Q4 – Ease of Understanding	3.38	56.25

Item	Mean	Agree / Strongly Agree (%)
Q5 – Performance Awareness	4.19	87.50
Q6 – Intention to Continue Use	4.00	81.25

Pedagogically, the findings support a "Teacher Expertise + MIDI Data" model. The teacher identifies the musical problem, selects a practice strategy, and evaluates the result; MIDI adds revisitable information for localization and self-monitoring. Used selectively, it may also support more independent practice by helping students compare attempts, but continuous visual monitoring could distract attention from sound and increase cognitive load. Its most appropriate use is therefore brief and problem-specific rather than continuous.

Several limitations constrain interpretation. The sample was small (N = 30), the intervention lasted only two weeks, and only measures 1-40 of Chopin's Etude Op. 10 No. 1 were used, limiting generalization across proficiency levels, repertoire, and longer-term learning. MIDI also captures pitch, timing, duration, and velocity but not tone color, pedaling, resonance, or complex musical expression; velocity should not be equated with dynamics in the broader musical sense. These limitations are particularly relevant to the non-significant secondary outcomes and to the baseline imbalance in accuracy.

Future studies should use larger samples, delayed post-tests, varied repertoire, and comparisons across proficiency levels [5]. More intuitive interfaces and extensions to pedaling, articulation, and rhythmic stability may further clarify where digital feedback provides the greatest practical value [4].

5. CONCLUSION

This study found significant learning in both instructional conditions. The MIDI group showed a larger unadjusted gain in accuracy ($p = .033$, $d = 0.82$), but the advantage was not significant after baseline adjustment ($p = .286$), and no significant between-group differences emerged for Dynamics, Musical Expression, or Overall Performance. MIDI visualization should therefore be understood as a teacher-guided aid rather than evidence of broadly superior instruction. Its practical value lies in making selected note and dynamic problems easier to observe and discuss, while learner feedback indicated generally positive acceptance. Larger, longer studies with varied repertoire are needed to identify the learners and tasks for which this approach is most useful.

REFERENCES

[1] Hattie, J., & Timperley, H. "The Power of Feedback." *Review of Educational Research*, vol. 77, no. 1, 2007, pp. 81–112. https://doi.org/10.3102/003465430298487.

[2] Hamond, L. F., Welch, G., & Himonides, E. "The Pedagogical Use of Visual Feedback for Enhancing Dynamics in Higher Education Piano Learning and Performance." *OPUS*, vol. 25, no. 3, 2019, pp. 581–601.

[3] Hamond, L. F., Himonides, E., & Welch, G. "The Nature of Feedback in Higher Education Studio-Based Piano Learning and Teaching with the Use of Digital Technology." *Journal of Music, Technology & Education*, vol. 13, no. 1, 2020, pp. 33–56. https://doi.org/10.1386/jmte_00015_1.

[4] Hamond, L. F. "Como o feedback visual em tempo real pode auxiliar a aprendizagem e performance de articulação em aulas de piano no ensino superior?" *Orfeu*, vol. 8, no. 2, 2023. https://doi.org/10.5965/2525530408022023e0211.

[5] Osaki, I., Fujioka, T., Schumann, E., & Maezawa, A. "Piano Practice Support System with Visual Feedback and Evaluation Protocols for Learning Experience Based on Subjective and Objective Metrics." *CSEDU 2026 – International Conference on Computer Supported Education*, 2026.

[6] Mohammadian, R., Pourroostaei Ardakani, S., & Zaraii Zavaraki, E. "A Systematic Review of Technology-Enhanced Music Learning Models: Impacts on Music Education." *Computers and Education Open*, vol. 10, 2026, 100354. https://doi.org/10.1016/j.caeo.2026.100354.

[7] Blanco, A. D., & Ramirez, R. "Evaluation of a Sound Quality Visual Feedback System for Bow Learning Technique in Violin Beginners: An EEG Study." *Frontiers in Psychology*, vol.

10, 2019, article 165. https://doi.org/10.3389/fpsyg.2019.00165.