The nature of feedback in higher education studio-based piano learning and teaching with the use of digital technology

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ABSTRACT

The aim of the current research was to investigate the nature of feedback when a digital technology system was introduced in the higher education (HE) piano studio alongside three teacher and student pairs in Brazil. Data were collected by using video-recorded observations of lessons, participant interviews, and also data related to the use of a specific technology. A thematic analysis of the resultant data suggests that participants used verbal and non-verbal feedback in three areas of lesson focus: music (score), performance (e.g. dynamics, articulation), and technology (Musical Instrument Digital Interface [MIDI] parameters). The application of technology seems to allow the focus of the lesson to become clearer, making students more aware of their performances and their learning processes. Data suggest that the engagement with technology varied across the three observed cases. There seems to be a valuable use for technology-mediated feedback; this could, in turn, optimize more traditional pedagogical approaches in HE piano learning and teaching, and also enrich private practice.

KEYWORDS: enhanced visual–auditory feedback, piano pedagogy, digital technology, technology-enhancing learning, piano performance, music education, piano roll, DAW Software

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INTRODUCTION

Feedback is a crucial component in the change and the potential for change in individual performance (Wiener 1961), in education (Hattie and Timperley 2007) and in enabling learning, such as for music learning (Welch 1985a, 1985b). Feedback is provided by a tutor to the learner to improve their performance (Hughes 2014; Irons 2007; Ferrell and Gray 2015), or to achieve a specific performance goal (Latham and Locke 1979). However, ensuring effective feedback has been a challenge in learning and teaching settings, since its efficacy depends on 'the type of feedback and the way it is given' (Hattie and Timperley 2007: 81).

Effective feedback involves a process whereby meaningful information is delivered not only by the teacher (Boud and Molloy 2013b; Hattie and Timperley 2007) but also by students' self-assessment and through their own self-regulatory skills (Hattie et al. 1996), alongside their critical background (Sadler 2010). Feedback is provided when current performance does not match the intended level of performance (Hattie and Timperley 2007). In addition, effective feedback seems to foster self-regulation mechanisms and increase learner autonomy (Hattie et al. 1996).

In instrumental and vocal learning and teaching, including piano learning, which is the focus of this research, the nature of feedback is both intraand interpersonal (Welch et al. 2005). Intrapersonal feedback happens inside the individual; interpersonal feedback happens between two or more individuals, or between one individual and one external source, such as technology. Intrapersonal feedback in piano learning and playing is mainly auditory (Banton 1995), visual (Banton 1995; Bishop and Goebl 2015, 2018), and proprioceptive, including kinaesthetic and tactile information (Brown and Palmer 2012; Wöllner and Williamon 2007).

The importance of visual feedback in piano playing when auditory feedback is absent or partially removed has been reported by several studies (e.g. Banton 1995; Bishop and Goebl 2015, 2018). Visual feedback played a more important role than auditory feedback in pianists' sight-reading, especially for pianists who had less sight-reading experience because they depend on watching their hands and the piano for movement accuracy (Banton 1995). Similarly, in the absence of auditory feedback from primo musicians, secondo pianists relied on visual feedback in the form of the head and body movements of primo musicians so as to synchronize the duo performance (Bishop and Goebl 2015, 2018).

Intrapersonal feedback also encompasses other internal processes that play a role in learning, such as the conscious–awareness state (Acitores 2011), metacognitive knowledge (Hallam 2001; Schraw and Dennison 1994), self-regulatory skills (Nielsen 2001), emotional state (e.g. Papageorgi et al. 2007) and a sense of self (Damasio 2000). Hallam (2001) argued that performers might regulate and control their musical practice through metacognition, which is related not only to practice and performance, but also to learning because it refers to 'thinking about thinking' (McPherson and Zimmerman 2002: 336). During practice and performance, HE students appeared to have used metacognitive competence, since they self-evaluated their performance progress by comparing their intended and actual performance outcomes (Nielsen 2001). For example, metacognitive knowledge can involve knowledge about the self and about strategies, and how, why and when to use these strategies. Underpinned by the definition of consciousness, Damasio also recognized '[having] within that [awake and operational] mind, an automatic, unprompted, undeduced sense of self as protagonist of the experience' as indispensable conditions of consciousness (2012: 161). Thus, these internal processes are not only part of the performance practice of HE instrument students, but also crucial in their learning process.

Interpersonal feedback in piano learning and teaching is mainly provided by the teacher. In piano learning, teacher feedback is customarily provided to inform students about what can be improved in their playing (whether in technique or interpretation). Specific feedback is needed to cause a positive change in student behaviour, that is, a change that has an impact on the student's learning process and performance outcomes (Kostka 1984; Siebenaler 1997; Speer 1994). Specific feedback is rarely provided by the student through self-assessment, such as verbal or non-verbal behaviour about musical performance parameters being addressed in the lesson, unless students are specifically invited by the teacher to reflect on their behaviour.

The types of teacher feedback that are commonly reported in piano learning and teaching literature are verbal and non-verbal. Several studies have reported various types of teacher verbal feedback such as giving directions, asking questions, providing information, giving verbal feedback (positive, negative or neutral), writing on the score and off-task comments (e.g. Benson and Fung 2005; Bryan 2004; Burwell 2010; Kostka 1984; Siebenaler 1997; Speer 1994; Welch et al. 2005). The same studies have also addressed teacher non-verbal feedback, such as by the teacher playing alongside the student, modelling (playing, or singing), imitating the student's performance, making hand gestures, conducting or tapping the beat,

giving non-verbal feedback, and other non-verbal behaviours such as smiling, laughing, nodding, shaking and facial expression. Specific feedback between teacher and student in HE piano studios seems to be meaningful when verbal and non-verbal behaviours are related with music performance parameters, such as dynamics, melodic and rhythm accuracy and articulation (Hamond 2013).

Analyses of musical performances have been conducted through technology-generated MIDI data, which were seen to have a relationship with specific musical performance parameters (e.g. Bernays and Traube 2014; Bresin and Battel 2000). In these studies, MIDI data were used to analyse recorded piano performances quantitatively by relating articulation, timing, dynamics or pedalling to MIDI parameters such as key velocity number, inter-onset-interval (IOI), key overlap time (KOT) and key detached time (KDT), variables that reveal data about pianist key and pedal activity (e.g. Bernays and Traube 2014;Bresin and Battel 2000; Palmer 1989; Repp 1996). Piano performances can also be analysed qualitatively through the piano roll visualization of the colours and sizes of the MIDI notes, and by relating these to selected musical performance parameters, such as dynamics and rhythmic accuracy, for example.

Although the one-to-one instrumental lesson paradigm can be seen as tailored to the needs of each student, many examples are available of a master-apprentice relationship, such as with a dominant teacher and a student dependent on the teacher's leadership (Hallam 1998; Jørgensen 2000). Results from an earlier pilot study (Hamond 2013) suggest that teachers and students do not necessarily share the same perspective on teaching and learning priorities, even if they have worked together extensively.

Interpersonal feedback can also occur between technology and the individual. Several studies in the area of motor control and learning, for example, have used technology to augment the feedback given to sports players. The learner may benefit from observing a video or a graphic representation of their performances alongside feedback provided by a coach (Magill 1989; Schmidt and Lee 2011). In the field of music education, technology can enhance learning (Himonides 2012) such as in HE music studios (King 2008) or in the music classroom (Savage 2007). There was evidence that technology use can promote a change in learning from a traditional to a transformative pedagogical approach (Savage 2007) by stimulating a more collaborative environment between individuals who are using the technology (King 2008),

especially with students who have been increasingly embracing technology in their lives (Zhukov 2013).

In instrumental and vocal learning and teaching, technology-based feedback can also be accessed, such as by using a metronome, audio- or video recording, both in real time and after the event, such as when it is provided by a teacher. Real-time visual feedback (RTVF) has been applied in the learning of advanced-level singing (Welch et al. 2005), in the learning and imitation of percussion rhythms (Brandmeyer 2006) and in piano improvisation (François et al. 2007). Several types of technology have been investigated in piano learning studies, including the use of video recording (Daniel 2001), audio recording (Zhukov 2010) and through piano-roll performance visualization (Riley 2005). However, the pedagogical use of digital technologies in one-to-one studio-based piano lessons still needs to be systematically investigated.

Instrumental and vocal students in HE, including piano students, have reported significant benefits of using technology in their self-study: they became more aware of their performances, developed self-assessment and self-critical thinking was enhanced (Carey and Grant 2014; Daniel 2001; Riley 2005; Zhukov 2010). In addition, students commonly use various forms of technology for their self-study (Zhukov 2013), since they are already involved with technologies in their personal lives outside the academy (Prensky 2001). Consequently, it has been argued that a change in teaching approach is needed, including leaning towards a greater use of technology to support piano learning and teaching.

AIMS

This research focused the nature of feedback in HE studio-based piano learning and teaching, by using digital technology. The specific purpose was to examine how technology might be used systematically in HE piano lessons to enhance learning.

METHODS

The current study was based on an assumption that the use of technology together with the feedback provided by the teacher in piano lessons has the potential to improve student learning. The research adopted an action-case approach, which can be defined as a ‘small scale

intervention with deep contextual understanding' (Braa and Vidgen 1999: 8) This hybrid approach encompasses elements of case study (interpretation/understanding of HE piano teaching and learning), and action research (intervention/change through the application of technology-mediated feedback).

PARTICIPANTS

Three teacher–student pairs in HE piano learning and teaching in Brazil were the main focus of this study, which examined the pedagogical use of technology-mediated feedback in HE piano studios. The participants in case studies A, B and C were adults. To select participants, the 'snowball strategy' proposed by Flick (2009: 110) was used by contacting piano teachers.

There were three criteria in selecting pairs of piano teachers and their students at HE level. The first criterion was choosing participants who had been working alongside each other in an HE institution; this was based on previous studies that suggested the benefits of using technology in this context. The second criterion was choosing pairs of teachers and students who had worked together on a regular weekly one-to-one basis for at least one term (ten weeks). This was to ensure that the exploratory use of technology would not interfere with their relationships or commitment towards a defined goal such as student performance; however, it transpired that all the participants had been working together for more than two years. The third criterion was related to the notion that piano pieces should be memorized to evaluate the use of RTVF whilst the students were playing the piece; this meant that if the student had not memorized their chosen piece, it would have been more challenging to evaluate whether they were looking at the computer screen or the music score.

ETHICAL REVIEW

The current study was conducted according to the ethical guidelines for educational research published by the British Education Research Association (BERA 2011) and was approved by the research ethics committee of the UCL Institute of Education. The participants in this study received an information sheet about the aims, focus and methods of this research study, and they had the opportunity to ask questions. Participation was voluntary; participants were informed that they had the right to withdraw at any time, without giving any reason and without

penalty. Moreover, the participants were asked to complete a consent form to be submitted either before or on the day of the data collection for the study.

The collected video, interview and MIDI data were treated confidentially. Participants' individual responses were anonymized in order to safeguard their personal data. The data were securely stored on a personal computer, which was password protected. Participants were informed that the findings of this study might be disseminated in conference presentations and academic publications, for example, but that personal details would be changed for these purposes.

DATA COLLECTION AND MATERIALS

Data collection was conducted between late December 2013 and February 2014; it was undertaken at an anonymous HE Brazilian institution through a pedagogical project that permitted access to their facilities. Three sources of data were collected: observation of videoed lessons (n = 6), interviews with participants (n =12) and MIDI data generated by technology. Although the original research project (Hamond 2017) involved data collection of video, interview and MIDI data, this article will focus on reporting research outcomes of the video data qualitative analyses with quantitative components only, by looking at the nature of feedback between teachers and students within the videoed piano lessons. Research outcomes where a particular musical performance parameter was a key focus for the teacher–student pairs were reported in another paper in terms of how dynamics and dynamic balance related to aspects of MIDI parameters, such as MIDI note colours and key velocity numbers displayed on the computer screen (for a more detailed discussion of the combined video, interview and MIDI data analyses, see Hamond et al. 2019).

The video data were collected by recording two piano lessons of the regular teacher–student pairs working on a chosen memorized piano piece with the technology being manipulated by the first author (the researcher). The three regular teacher–student pairs chose to work on selected movements of western classical sonatas during both lessons. Table 1 shows details of each of the three case studies according to their respective chosen piano pieces, and the duration of videoed lessons with teachers and students.

Teacher and student pairs	Chosen memorized piano piece	Piano student	Lesson 1 (duration)	Lesson 2 (duration)
Case study A	Mozart Piano Sonata No.16 in C major, K. 545, second movement	Second instrument	1h 13min	1h 4min
Case study B	Beethoven Piano Sonata No.9 in E major, Op.14, No.1, first movement	Principal instrument	48 min	43 min
Case study C	Mozart Piano Sonata No.2 in F major, K. 280, first movement	Principal instrument	48 min	52 min

Table 1: Duration of each observed piano lesson per case study (adapted from Hamond 2017: 162).

The equipment used in the study had a dual function of both data collection and a mediating technology to provide additional visual and auditory feedback in piano lessons. There were two digital cameras, two tripods for the digital cameras, a voice recorder and a digital piano, MIDI cables, a laptop computer running DAW software Cockos' REAPER (Rapid Environment for Audio Production, Engineering, and Recording – http://www.reaper.fm/) through a MIDI interface, an additional computer screen, and a VGA cable. Teachers and their students worked on a memorized piece (one movement of a classical sonata) from their current study repertoire in two piano lessons. The lead researcher (first author) played the role of a facilitator by manipulating the technology in piano lessons.

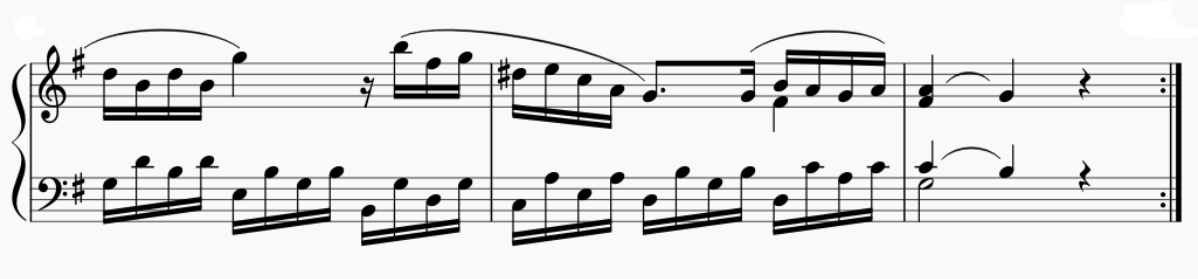


Figure 1a: Mozart Piano Sonata No. 16 in C major, K. 545, fragment, second movement, bars 14–16.

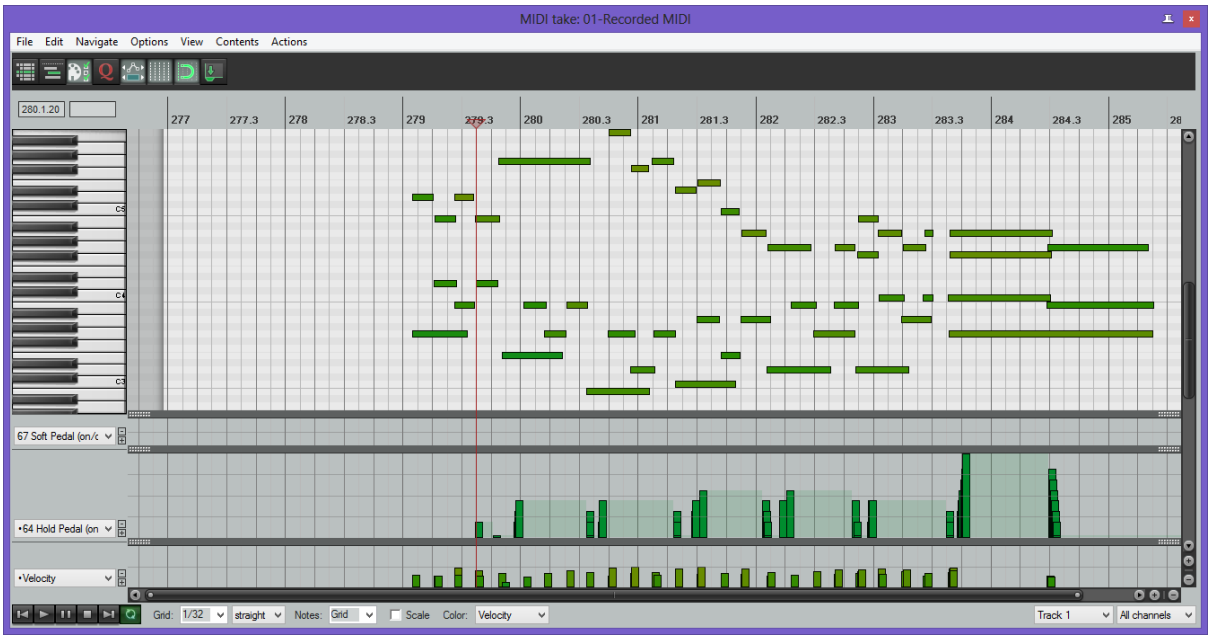


Figure 1b: DAW software screenshot showing the recorded data correspondent to the student's playing bars 14-16 of the Mozart Piano Sonata No. 16 in C major, K. 545, fragment, second movement (Hamond 2017: 264).

The MIDI data generated by technology were recorded while a chosen piece was played by one of the participants and that could be accessed later through playback (additional auditory feedback). The computer screen visualization was in the form of a piano roll (additional visual feedback); this offered two additional types of feedback to the teacher and student: visual and auditory, which could be used in real time or post hoc (playback). Additional types of visual–auditory feedback provided information on MIDI parameters, for example: (1) sizes and spaces noted on the visualization of MIDI notes that can be associated with rhythmic accuracy (see examples in Figure 1a and 1b); (2) asynchrony of MIDI notes with articulation; (3) the presence or absence of MIDI notes with melodic accuracy and (4) MIDI note colours with dynamics (intensity).

DATA ANALYSIS

The current study was essentially a qualitative social research study with quantitative aspects in which the stance of a constructivist paradigm is adopted to make sense of the phenomenon, that is, the application of technology in HE piano learning and teaching. Data analyses were conducted by using the computer-assisted qualitative data analysis (CAQDA) software called NVivo10 QRS International (http://www.qsrinternational.com/what-is-nvivo).

Video qualitative data analysis (video QDA) for verbal and non-verbal feedback on musical performance parameters encompasses qualitative data analysis with a quantitative component. A thematic data analysis (Braun and Clarke 2008) involved observing and interpreting categories of verbal and nonverbal behaviour of participants, and the pedagogical use of technology-mediated feedback in the two videoed piano lessons. This was conducted for each case study to illustrate their respective characteristics, differences and similarities. The Ph.D. study on which this article is based (Hamond 2017) reported on both the duration and frequency of each type of observed behaviour per participant; this was in line with previous research (Benson and Fung 2005; Burwell 2010; Welch et al. 2005). In this study, *duration* described the time spent in seconds and the percentage of time that each type of coded behaviour occurred within the total lesson time. *Frequency* described the number of times that each type of coded behaviour was observed in each lesson. In this current article, however, we will focus only on the research outcomes related to the duration of each observed behaviour (in seconds and per cent). Although a large amount of quantitative data was generated, statistical analyses were not conducted due to the small number of observed piano lessons ($n = 6$), unlike the larger numbers obtained in previous studies (Creech 2012).

The video QDA addressed three main categories: talk, playing and feedback. The *talk* category encompassed the sum of all subcategories of verbal behaviour, such as the teacher providing information, giving direction, general feedback, off-task comments, emotional responses, asking questions, responding, commenting on previous experiences, providing monosyllabic responses, and other verbalizations. The *playing* category involved several subcategories related to playing, such as imitating, modelling, and practising, among others selected from all non-verbal behaviours. The *feedback* category encompassed types of information (verbal and non-verbal) generated from a cross-tabulation between the categories of behaviours (verbal and non-verbal) and the categories of musical performance parameters.

The first focus of feedback analyses in the case studies involved investigating the sum of the behavioural patterns of both participants (student and teacher) for talk, playing and feedback. The second focus involved investigating talk, playing and feedback for each participant, that is, for the student and teacher separately. The third and final phase of the progressive analysis focused solely on the nature of the feedback. This analysis investigated the types of specific verbal and non-verbal feedback given by teachers and students. The

specific types of feedback observed on the videoed lessons addressed aspects related to one of the following three areas: music, performance or technology. The verbal or non-verbal feedback (1) on *music* denoted some kind of information about the musical notation (the score); (2) on *performance* conveyed information about, for example, dynamics, articulation, rhythmic and melodic accuracy, and pedalling and (3) on *technology* focused on the notational display with MIDI parameters such as size, colour and position of MIDI notes in the piano roll.

RESULTS

In the first stage of analysis, findings from the video QDA with quantitative components examined the sum of all participants' behaviours; that is, no differentiation was made between teacher and student behaviour. The total amount of *talk, playing* and *feedback* was investigated for duration (per cent of the total lesson time) across the three case studies (Figure 2). A lot of time was spent on *talk* across the three case studies. Time devoted to talking in both lessons combined, and it ranged from 49% to 54% of lesson time across all six lessons (M_2 = 51%). The main difference between case studies was in terms of the length of time spent *playing* (M = 37%). Average playing time was observed less in case study A (M = 20%) than in the other two case studies B (M = 43%) and C (M = 46%). Feedback, both verbal and non-verbal, represented a relatively high length of time across all case studies, averaging 37% of all six lessons with a range of between 33% and 40%.

Here the behaviours *talk, playing* and *feedback* were analysed per participant separately, that is, teacher and student behaviour (Figure 3). Most of the lesson time across case studies was devoted to teacher talk, student playing, and teacher feedback. Average teacher talk time accounted for 42% of total lesson time across all six lessons, with slight differences between case studies. Average playing time was mostly accounted for by students, with 30% of total lesson time across all six lessons. However, average student playing time differed across case studies, with 19%, 42% and 28% of total lesson time being taken up by playing in case studies A, B and C, respectively. Observed differences in student playing time suggest that each case study demonstrates a particular pedagogical style by the teacher. Feedback, both verbal and nonverbal, was predominantly delivered by the teacher, accounting for 33% of total lesson time across all six lessons, with slight differences between case studies (range 28% to 38%).

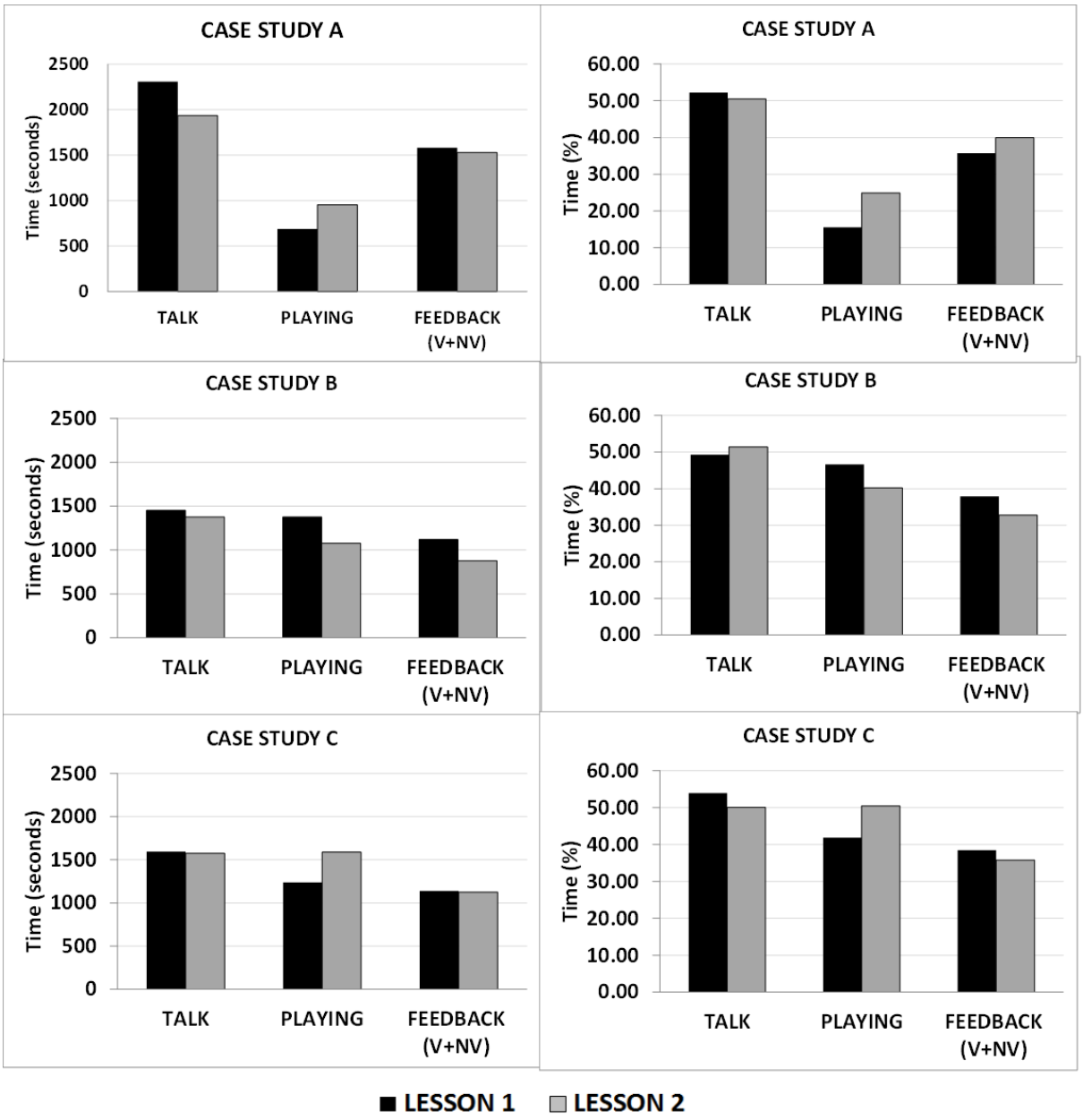


Figure 2: Time spent (seconds and per cent) on talk, playing and feedback (verbal and non-verbal) per case study and lesson (adapted from Hamond 2017: 185).

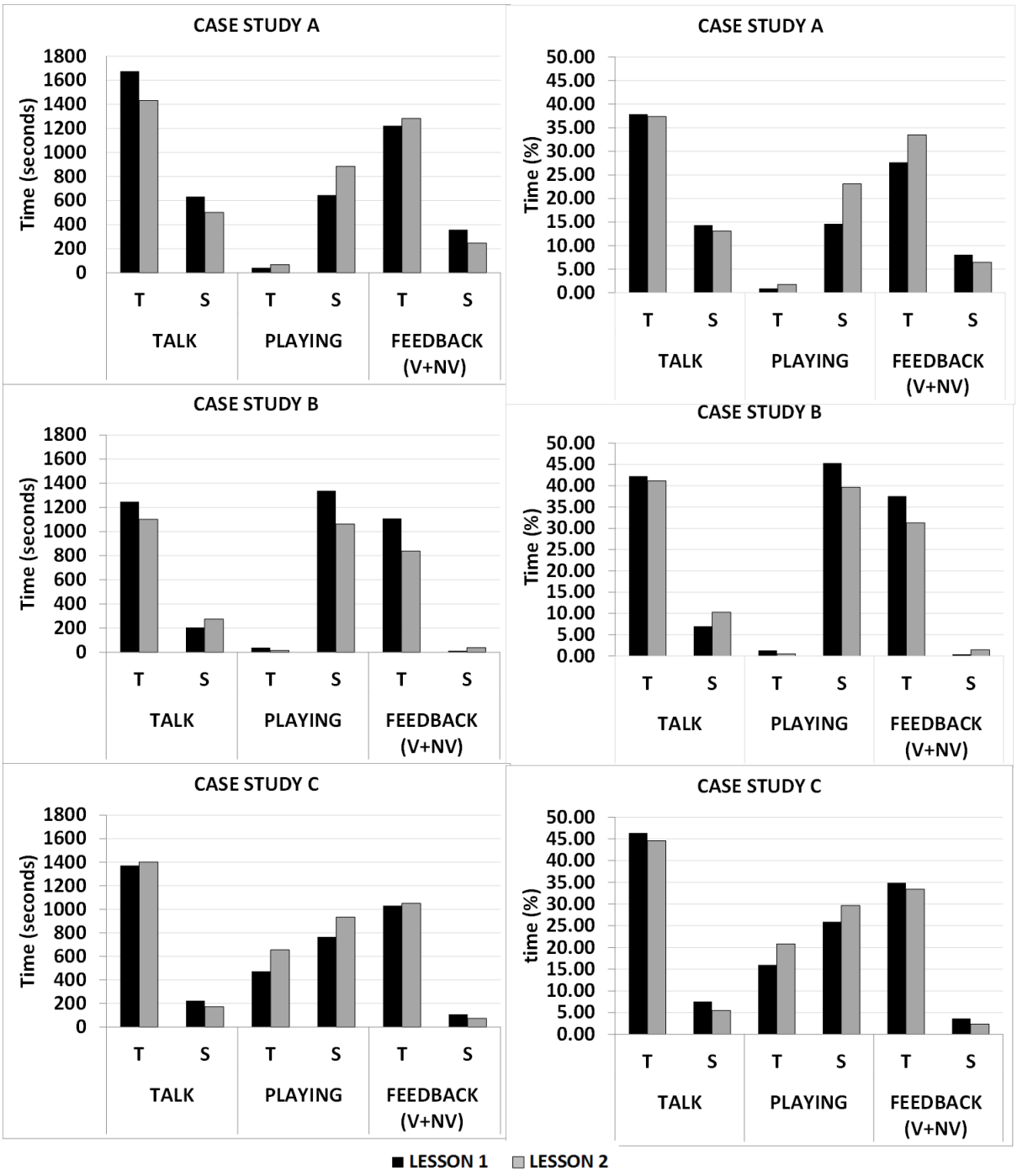


Figure 3: Time spent (seconds and per cent) on talk, playing and feedback per participant per case study (adapted from Hamond 2017: 188).

In contrast, minimal time was spent on student talk, teacher playing, and student feedback across the three case studies. Average student talk time accounted for 10% of total lesson time across all six lessons. Average student talk time in case study A accounted for 14% over lessons, suggesting that this particular student was making more comments in lessons than the students in the other two case studies. Average teacher playing time was also minimal,

accounting for 1% in case studies A and B. However, teacher playing time was substantially higher in case study C, where it accounted for 18% of the total lesson time. This suggests that this particular teacher was modelling a desired musical behaviour as well as talking, corroborating the existence of different teaching styles as commented on earlier. Average student feedback time was minimal across the case studies, accounting for 4% of total lesson time across all six lessons. Student feedback time in case study A accounted for approximately 7% across lessons, suggesting that this particular student was self-evaluating their performance within lessons.

Finally, types of verbal and non-verbal feedback, which were addressed in relation to musical performance parameters in the three main areas, namely, music, performance and technology, were investigated across three case studies (Figure 4).

The three case studies demonstrated different patterns of verbal and non-verbal feedback, although there were some similarities. Verbal feedback tended to be relatively evenly distributed across the three categories of music, performance and technology in case studies A and B, but it was biased towards performance in case study C. In this latter case study, teacher C spent much less time focused on technology (M = 2%) compared with teachers A (M = 7%) and B (M = 7%). Teacher C devoted approximately double the length of time to performance aspects (M = 16%) when compared with teachers A (M = 8%) and B (M = 8%). There was a significant difference for student verbal feedback on technology across case studies. Students A and B devoted 2% and 1% of the lesson time to technology, respectively, whereas student C did not discuss it at all. With regard to non-verbal feedback, the behaviour of each teacher was biased towards performance. Teachers A and C spent 8% of lesson time across lessons in delivering non-verbal feedback on performance, whereas teacher B devoted 13% across lessons. The following paragraphs report on the nature of feedback within each of the three case studies with regards to time.

With regard to individual teaching styles, teacher A involved much more non-verbal feedback in the second lesson (M = 17%) than in the first (M = 5%). Average teacher verbal and non-verbal feedback on performance was predominant throughout both lessons, accounting for 16% of the total lesson time, with both verbal and non-verbal feedback accounting for 8% each. Average teacher verbal feedback emphasized performance, then

music, accounting for 8% and 6% of total lesson time, respectively. Teacher verbal feedback on technology was consistent, accounting for 6% of total lesson time throughout lessons. Student verbal and non-verbal feedback occurred for all types of feedback, apart from verbal feedback on performance. Average student feedback on technology stood at 3% of total lesson time. The total student feedback time accounted for 7%. This indicates that student A was supporting the teacher by providing comments on technology in lesson 1. Teacher A adopted a collaborative teaching style, which arguably facilitates a more dynamic learning process. In case study A, opportunities were provided for the student to engage in verbal and non-verbal behaviours, and arguably to develop a more independent and autonomous learning style.

In case study B, although the teacher used more verbal than non-verbal feedback, 15% of the total lesson time was spent on non-verbal feedback. Teacher B's verbal feedback was relatively evenly distributed throughout the lessons, emphasizing performance, technology and music, accounting for 8%, 6% and 5% of total lesson time, respectively. Similar to teacher A, teacher B involved non-verbal feedback on performance, accounting for 13%. However, teacher B spent little time delivering non-verbal feedback on music (M = 1%) and on technology (M = 1%). There was an almost total absence of student feedback in case study B. Student verbal feedback on technology stood for 1% of total lesson time over lessons. Student B spent no time on the observed forms of non-verbal feedback. This evidence suggests a strong master–apprentice model of teaching, with teacher verbal behaviour dominant.

In case study C, the teacher also emphasized verbal feedback on performance, which stood at 16% in each lesson. However, teacher C spent less time on verbal feedback on music and technology, accounting for 7% and 2%, respectively. Also, student C spent no time on the observed forms of verbal feedback. Similar to teachers A and B, teacher C provided non-verbal feedback on performance, accounting for approximately 8%. The student only contributed 3% of average non-verbal feedback time on performance. Teacher A adopted a more collaborative teaching style (as implied by the data distribution), whereas both teachers B and C demonstrated a stronger master–apprenticeship model of piano learning and teaching. Teacher B dominates verbally, whereas teacher C spends more time actually playing, and students B and C primarily contribute to their lessons by playing.

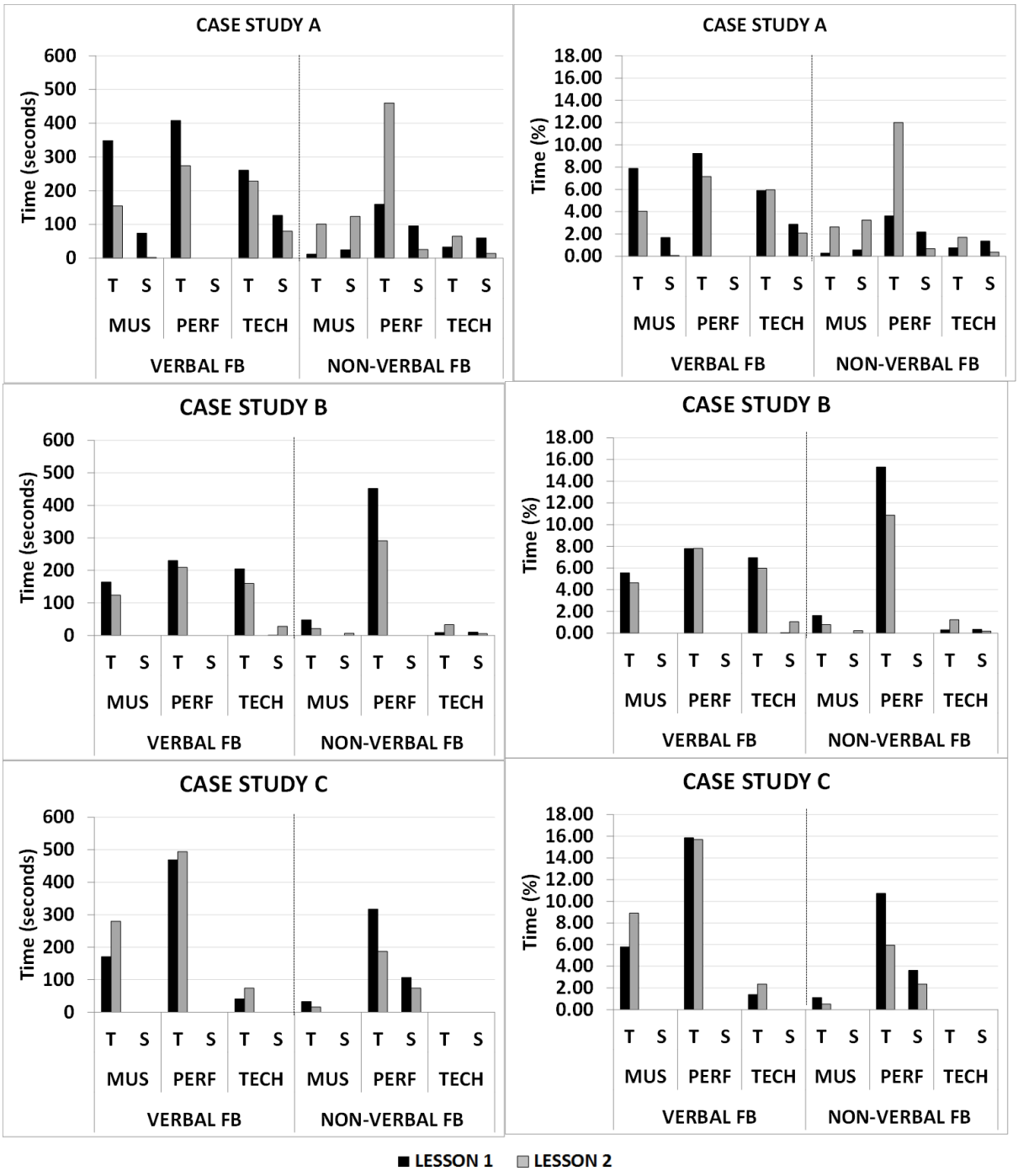


Figure 4: Time spent (seconds and per cent) on feedback (verbal and non-verbal feedback) per participant per case study for the three foci (music, performance, technology) (adapted from Hamond 2017: 193).

Specific types of verbal feedback were mostly in the form of providing information and giving directions across the three case studies. Asking questions was observed only in case studies A and B. Verbal feedback was delivered by teachers or students for: (1) music, such as the music structure, harmony and tonality of the chosen piece; (2) performance, such as dynamics, tempo, articulation, rhythmic accuracy, phrasing, pedalling, technique, motor

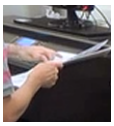
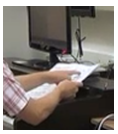
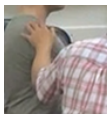
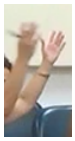
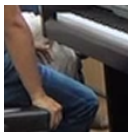
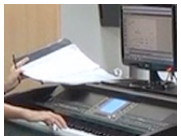
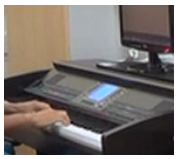
control issues, and fingering and (3) technology, such as MIDI notes sizes, colours, asynchrony, key velocity and numbers. Examples of verbal feedback types are shown in Table 2.

Similarly, types of specific non-verbal feedback were delivered by teachers and students across the three case studies. Types of non-verbal feedback were self-explanatory; they were related to music, performance and technology. They were mainly in the form of body and head movements for tempo, such as nodding the head or moving the body alongside student playing, pointing to the score for musical structure, playing to demonstrate harmony and tonality, and gesturing for tempo. Differences in the types of non-verbal feedback were observed across case studies. For example, playing examples for articulation, and physical touching for motor control issues were noticed in case studies A and C. Similarly, pointing to the computer screen for MIDI parameters, and gesturing for technique and for motor control issues were observed in case studies A and B. Other non-verbal feedback forms were observed in specific case studies, such as playing for technique and tempo, and singing for rhythmic accuracy in case study C. Gesturing as a type of non-verbal feedback was noticed in case study C when snapping fingers and tapping hands or feet for rhythmic accuracy. Gesturing was also noticed in case study B for phrasing, articulation and dynamics. Examples showing still images from video shots of non-verbal feedback on music, performance and technology across the case studies are illustrated in Table 3. It should be noted that to ensure anonymity, the selected images do not show faces of participants.

Musical performance parameters	Examples of verbal feedback	Case study and lesson
Music	S: in this section here, in this part. (student verbal feedback on music: providing information on musical structure)	Case study A lesson 1
	T: For example, I wanted that we could do until here, ... until that first cadence. (teacher verbal feedback on music: giving direction on musical structure)	Case study A lesson 2
	T: you cannot test the opening (of the piece) ... it is sounding like you are testing it (teacher verbal feedback on music: providing information on musical structure)	Case study B lesson 2
	T: Can we repeat the beginning again? (teacher verbal feedback on music: giving directions on musical structure)	Case study B lesson 1
	T: but when you go to … to … to the fifth bar…which is what happens here, (teacher verbal feedback on music: providing information on musical structure)	Case study C lesson 1
Performance	T: because sometimes you … The silences, I don't know if you can perceive… you shorten a bit, right, some silences. (teacher verbal feedback on performance: providing information on rhythmic accuracy)	Case study A lesson1
	T: Yeah, because it is clear that you hold the… bottom note and this one, and this one (you hold) less (teacher verbal feedback on performance: providing information on articulation)	Case study A lesson 1
	T: I think I would do with the fourth (finger)… I always thought the fourth (finger) was better (inint) … than the third (finger), and the second (finger) (teacher verbal feedback on performance: providing information on fingering)	Case study B lesson 2
	T: And ... an exact pause… That's it. And do not change the rhythm, right… T counting T saying tatata (teacher verbal feedback on performance: giving directions on rhythmic accuracy)	Case study C lesson 1
Technology	T: Then here there is a red colour much more… but here… then, it comes back to the green colour. (teacher verbal feedback on technology: providing information on MIDI parameters)	Case study A lesson 1
	S: Yeah, you can see that this was tenser, this got darker… and here it came back lighter… but there are some details that you can see… there are some changes, this you can see. (student verbal feedback on technology: providing information on MIDI parameters)	Case study A lesson 1
	T: So, could you put this playback now whilst he plays the left hand at the same time? (teacher verbal feedback on technology: giving directions on MIDI recording version)	Case study A lesson 2
	T: Let's listen to the beginning for you to realize this?… Come on, let's see… Let's listen to it again (teacher verbal feedback on technology: giving direction on MIDI recording version)	Case study B lesson 2
	S: These notes (MIDI notes) had to be (should have been) longer. (student verbal feedback on technology: providing information on MIDI parameters)	Case study B lesson 2
	T: You can put, for example, the first (recording version), only the first part, from the very first time that he played, until there … (teacher verbal feedback on technology: giving directions on MIDI recording version)	Case study C lesson 1

Key: T represents teachers and S represents students.

Table 2: Examples of verbal feedback on music, performance and technology delivered by teacher and student per case study and per lesson (adapted from Hamond 2017: 201).

Musical performannce parameters	Picture from the video shot	Examples of non-verbal feedback	Case study and Lesson
Music		Student non-verbal feedback on music (pointing to the music score for music structure)	Case study C lesson 2
		Teacher non-verbal feedback on music (pointing to the music score for music structure)	Case study C lesson 1
Performance		Teacher non-verbal feedback on performance (touching student shoulder for motor control issues)	Case study C lesson 1
		Teacher non-verbal feedback on performance (gestures for phrasing)	Case study B lesson 1
		Teacher non-verbal feedback on performance (gestures for motor control issues)	Case study B lesson 2
		Student non-verbal feedback on performance (gestures - left hand - for motor control issues, i.e. playing on the lap / mute playing)	Case study A lesson 1
		Teacher non-verbal feedback on performance (playing for harmony and tonality)	Case study A lesson 2
		Student non-verbal feedback on performance (touching for motor control issues, i.e. placing hands on the piano but not playing)	Case study A lesson 1
Technology		Student non-verbal feedback on technology (pointing to the computer screen for MIDI parameters)	Case study A lesson 2
		Teacher non-verbal feedback on technology (pointing to the computer screen for MIDI parameters)	Case study A lesson 2

Key: T represents teachers and S represents students.

Table 3: Examples of non-verbal feedback on music, performance and technology delivered by teacher and student per case study and lesson (adapted from Hamond 2017: 202).

Alongside specific verbal and non-verbal feedback across case studies, teacher general feedback was a subcategory of *talk*, since talk incorporated the sum of all verbal behaviours. In contrast, general teacher feedback is delivered only in terms of positive, negative or ambiguous feedback. General teacher feedback gives students an idea of whether their performance went well or needs to be improved, expressed through positive or negative feedback, respectively. At other times, it is difficult to gauge what the teacher wanted to convey as the recorded evidence appears ambiguous. The investigation of general feedback adds understanding to the context of each case study, enabling the differences and similarities between cases to be seen more clearly. Examples of the three forms of general teacher feedback – positive, negative and ambiguous – that were provided by the teacher in each case study are illustrated in Table 4. Overall, relatively little time was observed to be spent on the provision of general feedback.

General Feedback	Examples
Positive	T: It really improved, right? (teacher C, lesson 2)
	T: I think you really cared enough (teacher B, lesson 2)
	T: Okay ... It is better ... The Sonata is going well. (teacher C, lesson 1)
	T: That's the idea. (teacher C, lesson 2)
	T: Congratulations. It improved a lot. (teacher C, lesson 2)
Negative	T: No, no, no. (teacher B, lesson 2)
	T: Yes. It's a little ... it's a little awkward, still. (teacher C, lesson 1)
	T: no ... no ... no ... no. (teacher C, lesson 1)
Ambiguous	T: Well... It didn't sound bad here. (teacher A, lesson 1)
	T: It doesn't make sense, (name of student C). (teacher C, lesson 1)

Table 4: Examples of general teacher feedback delivered in each case study (Hamond 2017: 203).

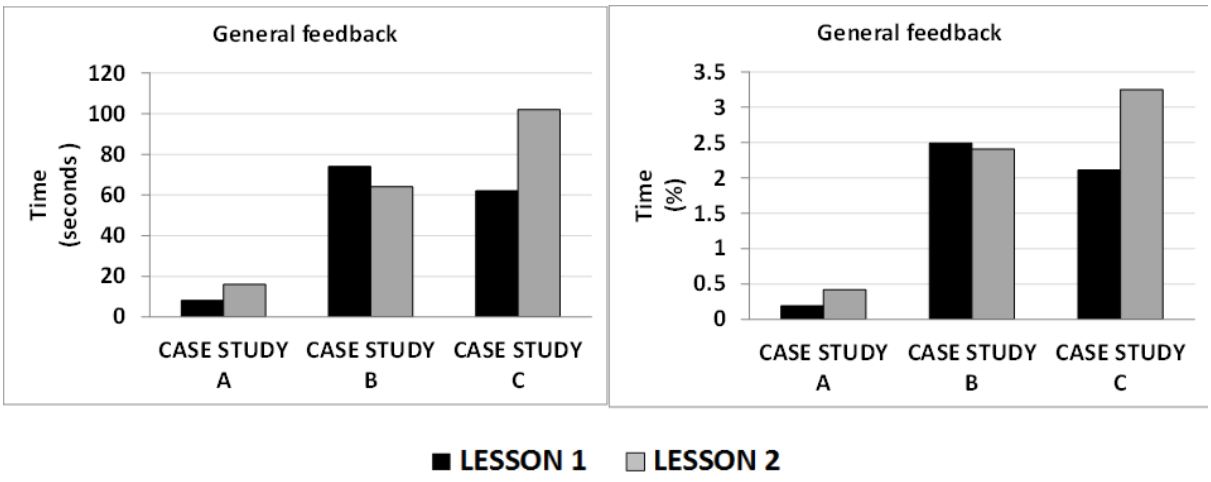


Figure 5: Time spent (seconds and per cent) on general teacher feedback per case study lesson (adapted from Hamond 2017: 204).

Figure 5 illustrates the distribution of time related to general feedback provided by the teacher in each of the three case studies. The average time spent on general teacher feedback was greater for the two teachers in case studies B (M = 2%) and C (M = 3%), whereas for teacher A, general feedback was virtually nil (M = 0%). General feedback time was consistent in case studies A and B, but it increased slightly in case study C, ranging from 2% to 3% between lessons 1 and 2. This evidence might indicate that general feedback is more observed in master–apprenticeship teaching styles than in collaborative teaching styles. Although specific rather than general feedback was the focus of this study, general feedback was reported on because it provides the overall context of the amount of feedback per case study. This study focused on specific feedback, as this is directly related to the musical performance parameters of music, performance and technology, rather than to general teacher comments on student performance outcomes, be this of approval, disapproval or ambiguity.

DISCUSSION

Despite the availability of technology in this study, the characteristics of traditional piano lessons were, nonetheless, observed. The main participant verbal and non-verbal behaviours that were observed in this study were grouped into three main categories: teacher talk, student playing and teacher feedback. Teacher talk was predominant across the three case studies, even when technology was applied in lessons, as evidenced in previous studies in conventional piano lessons (Benson and Fung 2005; Bryan 2004; Kostka 1984; Siebenaler 1997; Speer 1994). In case studies A and B, student playing was predominant. However, in case study C, the teacher

modelled a great deal through playing; here, the teacher dominated the lesson by playing as well as talking. Findings suggest that student playing occurs in response to teacher feedback. This evidence implies a likely circular or dependent relationship between teacher and student, something that concurs with findings from previous research (Burwell 2010).

Characteristics of traditional piano lessons are mainly related to the use of the musical score as a source for interpretation, where teachers and students commonly discuss this by making associations between musical notation and musical performance (Bautista et al. 2009; Hultberg 2002). Types of feedback that were observed in this study can also be found in conventional instrumental lessons with master–apprenticeship teaching styles. Verbal feedback (e.g. providing information, asking questions) and non-verbal feedback (e.g. body and head movements, pointing to the score) in this study were linked to *music* and *performance*, and provided by the teacher, as reported in research on conventional piano learning and teaching, with regard to dynamics, tempo, articulation and musical structure (Bryan 2004; Chaffin and Imreh 2002; Keithley 2004). Associations between musical notation and musical performance suggest traditional pedagogical approaches (Hallam 1998; Jørgensen 2000).

In contrast, when technology is applied in a piano studio setting, technology offers alternative means for discussion through associations between technology and musical notation, and between technology and musical performance. This discussion can happen through verbal or non-verbal behaviours, such as providing information and pointing to the computer screen to discuss what visual information the participants can see and make sense of on the screen. These findings suggest that participants were able to make associations between technology and the other parameters, for example, MIDI key velocity numbers and dynamics, and IOI and timing, which agree with those of previous experimental studies (Bernays and Traube 2014; Bresin and Battel 2000; Palmer 1989; Repp 1996). Feedback on *technology* (notably MIDI parameters) was different from the feedback types in traditional approaches (*music* and *performance*), and could also be provided by either the teacher or the student, suggesting transformative pedagogical approaches (Carey and Grant 2015; Creech and Gaunt 2012).

*Inter*personal feedback was seen to be extrinsic to each individual participant of this study, that is, coming from the teacher, or the technology. Findings of this study agree with

previous research that addressed the notion that effective piano learning and teaching happens with specific feedback (Kostka 1984; Siebenaler 1997; Speer 1994) when a verbal or non-verbal behaviour is combined with a parameter (music, performance or technology) to make clearer to the student any aspect of his/her piano learning or performance; this can, in turn, improve student autonomy (Creech 2012).

*Intra*personal feedback was seen to be intrinsic to each individual participant of this study, that is, the teacher or the student when doing self-assessment. Intrapersonal feedback is related to sensory feedback, such as visual, auditory and proprioceptive feedback, and associations between these (Bishop and Goebl 2015, 2018; Brown and Palmer 2012; Halwani et al. 2011; Moore et al. 2016). In this study, when digital technology is used in piano lessons, it generated additional feedback alongside teacher feedback. Students' intrapersonal feedback was augmented through the additional technology-mediated feedback in terms of visual feedback as information available on the computer screen in real time and post hoc, and post hoc auditory feedback since the recorded data could be played back to the participants at any moment of the lesson. This enhanced intrapersonal feedback might have had an impact on their piano learning and performance, when combined with the interpersonal feedback between teacher and student.

In a piano lesson that uses technology-mediated feedback, it is not solely the teacher who becomes responsible for providing feedback; students could provide feedback on their own performances through verbal and nonverbal feedback, as both their visual and auditory intrapersonal feedback was enhanced. Findings of this study are in line with those of previous research (Hattie and Timperley 2007; Magill 1989; Schmidt and Lee 2011; Welch et al. 2005), which acknowledged that feedback also depends on the internal systems of students. The use of technology can engender a change in learning through the adoption of a transformative pedagogical approach (Carey and Grant 2014). This can be illustrated by the collaborative and transformative approach observed in case study A in comparison to the more customarily conventional and master–apprentice approaches noted in case studies B and C. This technology-based approach supports and extends traditional teaching, due to the coexistence of similarities, in terms of music and performance, and differences, in terms of technology and associations with conventional parameters, in the lesson context of piano studios; this agrees with findings of previous research (Savage 2007).

FINAL REMARKS

The application of technology in HE piano studios can have an impact on both inter- and intrapersonal feedback. First, digital technology had an effect on interpersonal feedback between teacher and student, since verbal and non-verbal feedback on technology was additional to and different from the common feedback types found in conventional piano lessons. The additional feedback on technology supported associations between technology, music and performance parameters, which made the lesson focus clearer. Second, digital technology augmented intrapersonal feedback of each individual participant by enhancing their sensory feedback and conscious awareness of their learning process. This occurred when technology-generated feedback was given as: (1) real-time and post hoc visual feedback and (2) post hoc auditory feedback. The interrelationships between the three topics of lesson discussion (technology, music and performance) appear to support the improvement of student learning and performance more objectively, and with a clearer lesson focus as reported. In conclusion, a piano learning and teaching setting using digital technology can involve similar approaches from the traditional instrumental lessons and different approaches, which can be used to enhance learning and contribute to a transformative pedagogical approach in HE piano studios.

The main point of future research may be to investigate potential applications of this technology system in a distance learning and teaching environment, such as synchronous or asynchronous online HE piano lessons. Another point for future research could be the possible application of this type of technology at other levels of piano expertise such as beginners or intermediate-level students, and also in advanced levels with other types of repertoire. This technology system allows teachers and students to share their performance-related data through the internet (online) and to discuss the visual feedback corresponding to aspects of piano performance in a very detailed way. It will be beneficial to teachers and students to learn that this could also complement video and audio recordings of performances they share. The use of visual feedback as a supporting tool in HE piano online learning and teaching could, therefore, augment the learning and teaching experience, making both student and teacher more aware of the executed movements and all keyboard and pedalling activity through the presence, absence and asynchronies of MIDI parameters. Overall, this has the potential to enhance the online learning experience, and to help teachers and students exploit the technology at their disposal.

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