An exploratory study of young children's technology-enabled improvisations

Angeliki Triantafyllaki,[*1] Christina Anagnostopoulou,[*2] Antonis Alexakis[*3]

[*] *Dept. of Music Studies, National and Kapodistrian University of Athens, Greece*
[1]a_triant@music.uoa.gr, [2]chrisa@music.uoa.gr, [3]tonisq@music.uoa.gr

ABSTRACT

Improvisation is now recognised as a central component of musical creativity. Although a relatively young area of study, its educational value has been discussed both musically and socially; young children's musical improvisations more specifically, have been explored through a variety of methods and from diverse paradigmatic viewpoints: cognitive, developmental, educational, sociological and others. The aim of this ongoing exploratory study is to enrich our understanding of the variety of ways young children experience musical improvisation, as this is enabled through the MIROR platform – an innovative adaptive system for children's music improvisation and composition, based on the *reflexive interaction paradigm*. In this paper we draw on data from an exploratory study conducted in November 2011 with eight year-old children, which aimed to explore the ways children engage with the MIROR Improvisation prototype. Three types of data are brought together for the analysis: thematic analysis of children's talk, descriptive analysis of children's turn-taking behaviour and computational music analysis. The research findings indicate connections between particular children's (a) turn-taking behavior and their embodied (gestural) understandings of how they played with the machine and (b) type of musical output and the density of their turn-taking behavior, which seem to indicate that the MIROR technology may in some children encourage particular ways of engagement, both musically and kinesthetically. Pedagogical issues arising from the integration of such technology-enabled improvisation in the primary school classroom are discussed.

Keywords: music improvisation, early childhood education, music technology, pedagogy

I. INTRODUCTION: IMPROVISATION AND NEW TECHNOLOGIES

Improvisation is now recognised as a central component of musical creativity (Webster, 2002; Ashley, 2009). Although a relatively young area of study, its educational value has been discussed both musically and socially, as has its collective and collaborative dimension (for an overview see Tafuri, 2006). Young children's musical improvisations, more specifically, have been explored through a variety of methods and from diverse paradigmatic viewpoints: cognitive, developmental, educational, sociological and others (see Azzara, 2002), while the object of research is also varied. For example, researchers have looked at the development of children as improvisers (Paananen, 2007; Brophy, 2005); improvisation as beneficial to the musical learning of very young children (Kratus, 1989); group improvisational behaviours (Burnard, 1999; 2002); and child-adult interaction as a source of children's creative behaviors (Young, 2003). 'Improvisation creates the possibility for children to create imaginative leaps and to be really present to music-making and discursive thinking, both their own and others' (Kanellopoulos, 2007:135). And as Ashley (2009) points out, improvisation is not an isolated element of human music-making; 'it connects musical structure our bodies and our sense of selves as individuals and members of social units in powerful ways' (p.419). Other areas, such as the introduction of new technologies to support children's improvisations, have received less attention.

The role of technology in music education is foregrounded in discussions about teacher effectiveness (Mills, 1997); young people's out-of-school musical lives (Folkestad, 2006); its impact on learner's creativity (Dillon, 2003); its complex relationship with creativity as agents for pedagogic change (Burnard, 2007); and processes of creative music-making with computers, particularly those of composing (Hickey, 1997; Collins, 2005). Addessi and Pachet (2005:14) note how 'new technologies in music education should be considered not only as 'instruments' for didactic support, but also as languages and experiences that affect, form and shape profoundly the processes of music learning and the musicality of children'. From a pedagogical point of view, technology is thought to transformatively change the way we teach by encouraging teachers to question what should be taught, how it should be taught, as well as where, when and why it should be taught (Burnard, 2007).

A relative unexplored area in music education technology is that of *interactive reflective music systems*, initially elaborated at the SONY Computer Science Laboratory in Paris, which represent a new generation of computationally augmented musical environments, the effectiveness of which has been largely demonstrated through prior studies carried out since 2003. The concept of this approach is to teach musical processes indirectly by putting the user in a situation where these processes are enacted not by the user, nor by the machine, but by the actual interaction between user and system (Addessi & Pachet, 2005). The idea behind IRMS, in musical terms, is based on the principle of repetition and variation, which are inherent properties in all types of music. The system, in order to produce a response, uses similar musical material of what is entered by the user, while at the same time adding something new to the session. The user, following this, bases his/her interaction on what he/she has already heard, perhaps keeping some musical content, perhaps dropping some, and perhaps introducing something new. In this way, a musical dialogue is created between the human and the system which shares many musical features, attributing various degrees of cohesion and coherence to the session.

The present study explores the use of such an innovative adaptive system for children's music improvisation and composition based on the reflexive interaction paradigm (for a theoretical treatise see paper by Addessi in these proceedings) and developed in the context of early childhood music education (FP7-ICT MIROR Project). The technology employed in the wider project of which the study reported here is part – the MIROR Impro prototype – aims to implement in early childhood settings computer-assisted improvisation.

This paper aims to do the following: (a) to explore children's perspectives on using the MIROR Impro prototype drawing on fieldnotes/informal discussions with children, (b) to supplement this analysis with data from the computational music analysis of children's music and a description of the child-machine interaction, as this was recorded by the MIROR Impro system, and (c) to highlight some implications of employing new technologies in primary music education.

II. METHODOLOGY AND METHOD

A. Research Procedure

The exploratory study was realized in November 2011 with 6 eight-year-old children, 3 girls and 3 boys in Athens. Each child engaged one-to-one with the prototype for 3 sessions across 1 week in a quiet room, following a preliminary meeting to allow familiarization with the equipment and the researcher. The equipment comprised of a laptop with the newest version of the MIROR Impro prototype at the time of the study and a KORG synthesizer connected through USB MIDI with the laptop.

The sample was selected purposely from a pool of around 10 children whose parents consented in their participation in our study, paying attention to select children with no musical background and an equal number of boys/girls.

In each session the child played with and without a visualization screen in front of them (simple representations of pitch, amplitude and tempo displayed on a laptop screen which was placed in front of/removed from children's visual span in each session) (Gromko & Russell, 2002; Gromko, 1994). The adult (researcher) did not interact with the child (as much as was possible). The children were asked to play as much as they liked during each set-up with and without the visualization, stopping when they were tired. The researcher then discussed informally with each child after their session about their experience of playing with the prototype, followed by a more structured discussion after their third session. It should be mentioned that the prototype can be set to respond with more or less variation to the child's input melody. In the particular exploratory study, the MIROR Impro setting was set to 'different', providing an output that was slightly varied to the child's input melody.

The data collected comprised of:

- Musical data from 18 sessions in MIDI format.
- Descriptive data on the turn-taking from 18 output files with statistical data from the system (hereafter named .CSV files).
- 6 Semi-structured interviews: after one week of playing with Impro.
- Fieldnotes: informal discussions with children after each session.

B. Analysis: theoretical considerations

i. *Description of turn-taking behaviours:* In this study we were interested in exploring the notion of turn-taking –i.e. interacting with another person, as an established notion of the process of learning (Rogoff, 1990) and a central component of the reflexive interaction paradigm. The musical dialogue that takes place between the child and the machine could be compared to infant-adult interactions which are based on repetition and variation (Stern, 1985); this interpersonal dimension has been found to potentially contribute to the development of young children's creativity (Young, 2003).

In order to describe children's turn-taking behavior, we drew on the recorded information provided by the MIROR prototype itself in the form of a .CSV file – a system- integrated function that allows the export of all notes played in the session (child's input and machine's output), providing information about the exported session, such as its name and parameters used as well as basic statistics on the session. For our descriptive analysis and in order to develop a general picture of children's turn-taking behaviours we drew on the information that stated the number of answers that the system produced (i.e. the higher the number of answers, the more dense the child-machine interaction). We were interested to identify sessions where the child-machine interaction was particularly dense and relate these sessions also to characteristics of the computational music analysis, as well as to children's perspectives of using the MIROR technology.

ii. *Computational music analysis:* The starting point of any music analysis task is always the music itself. In MIROR, the study of the children's musical output can reveal interesting aspects of their perceptions, experiences and ways the use the system. We concentrate on two distinct types of analysis: The first one is pattern discovery, where repeated patterns in the children's melodies are brought forward, evaluated and discussed, and the second one is clustering of all children's melodies into categories, to see whether there exist specific categories of melodies in the corpus. In our study, children's improvisations made out a corpus of melodies in a symbolic format since they were played on a MIDI keyboard, which were then subjected to computational music analysis in order to explore further children's musical use of the technology (for precise methodology of the pattern discovery technique on a different corpus see paper by Anagnostopoulou, Alexakis & Triantafyllaki, in these Proceedings).

The results of this analysis then fed back to the analysis of children's turn-taking behavior as well as their perspectives of using the technology.

iii. Children's perspectives: Studies looking at children's perspectives of any form of music-making must begin with acknowledging their 'messy, multi-layered and non-normative character' (Spyrou, 2011:151). Further, it must begin with the certainty that exploring children's thinking about their own music relies on the precondition of experimentation, not only with music but also with interpretation of this thinking about music (Kanellopoulos, 2007). Indeed, any interpretation of children's talk cannot be complete without taking into account the larger sociocultural context in which their voice is situated (Wertsch, 1991); and as Bakhtin (1981) might argue in his dialogic take on human communication, children's talk is mediated by the discourses they are able to access and which represent the interests, assumptions and values of particular groups. Such discourses might include in the case of music learning particular assumptions about 'knowing how to make music'; about the 'difficulty' of certain musical instruments; or about how music 'should sound'. When several children in our study initially felt unease when playing with the keyboard (which was used as a medium for the technology), we interpreted their perspectives as situated in the above assumptions, or else, in the dominant ideological and cultural discourses that produced them.

III. RESULTS

A. Turn-taking behaviour

The findings from the CSV function are first presented in order to describe children's turn-taking behavior with and without the visualization screen across 2 different parameters, gender and experience (i.e. across 3 sessions). The turn-taking behavior is calculated on the basis of the number of answers from MIROR Impro during each child's session with and without the visualization, as these were recorded by the program.

Table 1: Turn-taking behavior according to gender

Set-up	With visualisation	Without visualisation	Overall turn-taking
BOYS			
Child 1	34	21	55
2	30	24	54
3	10	19	29
OVERALL BOYS	**74**	**64**	**138**
GIRLS			
4	51	57	108
5	52	54	106
6	75	73	148
OVERALL GIRLS	**178**	**184**	**362**

From these results in Table 1 we can see that children's turn-taking behavior is nearly the same when they interact with MIROR Impro with the visualization and without. Indeed, even within this small sample there seems to be a strong similarity in the level of turn-taking across the two set-ups. Therefore, it would seem that the visualization does not enhance children's turn-taking behaviours. The same finding seems to be the case when comparing levels of turn-taking across boys and girls with and without the visualisation.

However, when examining the levels of turn-taking across boys and girls regardless of the visualization parameter we see that girls seem to interact with MI more than boys. Indeed, their interaction with the prototype seems nearly doubled (362 number of answers from MI) to that of boys in the sample (138 number of answers from MI).

Table 2 examines how the children's experience of engaging with MI with and without visualization might shift across sessions. In this table we highlight in bold where there seems to be a decrease to a greater or lesser extent in the level of turn-taking behaviour across sessions 1 & 3, regardless of the visualization parameter.

Table 2: Turn-taking behavior according to experience

Session	1	2	3
Child 1	**Y=19 N=15**	Y=11 N=4	**Y=4 N=2**
2	**Y=26 N=6**	Y=0 N=13	**Y=4 N=5**
3	**Y=9 N=3**	Y=1 N=16	**Y=0 N=0**
OVERALL BOYS	**Y=54 N=24**	Y=12 N=33	**Y=8 N=7**
4	**Y=23 N=25**	Y=11 N=13	**Y=17 N=19**
5	**Y=29 N=21**	Y=10 N=16	**Y=13 N=17**
6	**Y=31 N=24**	Y=14 N=30	**Y=30 N=19**
OVERALL GIRLS	**Y=83 N=70**	Y=35 N=59	**Y=60 N=55**

Key: Y =with visualization, N=without visualization

As is evident in Table 2, the turn-taking behavior seems to decrease across sessions, regardless of whether the child plays with or without the visualization parameter. An interesting finding that arises when separating the levels of turn-taking in accordance to session is evident in the 1st session. While we reported in Table 1 that children's overall levels of turn-taking seemed similar with and without the visualization parameter, we see now in Table 2 that in Session 1 children's levels of turn-taking behaviours seems higher with the visualization than without. This might indicate that once the novelty of using the visualization wears off by the third session, the children interact less with the prototype. It might be interesting, however, to note that girls' turn-taking with the visualization seems to decrease by the 2nd session and then increase slightly again by the 3rd. Other parameters, such as non-intervention from adults, were kept constant across sessions.

B. Children's perspectives

In this second sub-section of the findings in this exploratory study we present children's talk about their interaction with MI. After each of the three sessions, the researcher discussed with children in an open-ended way their engagement with MIROR ('what happens when you play') and conducted more structured interviews after their final session ('what did you think of the music', 'is it same or different to what you play', 'can you remember what you played').

i. *Who follows who?* An important principle of MIROR Impro is that children are in control of the situation, and that they actually attempt to 'teach' the system their 'own' music. More than half the sample supports that it is MIROR who follows them and not the other way round. This is important as it may be an indication that children understand that they 'lead' MIROR or 'teach' it what they play: i.e. "I did not play what it played – it played what I played" (Child 5) *ii. The type of response*. Around half the sample – all girls - suggests that it preferred when the system responded with more variation than when the response was more similar to their own input melodies: “It responds differently to me so that the music is nicer” (Child 4). Child 6 tells us that the different response of MIROR Impro was pleasant to listen to and that it helped her do more with her playing, i.e. “I played more notes as it played more notes”. So, while in initial discussions the child-machine interaction seems to be initiated by the MIROR Impro prototype, the development of the interaction is assisted by the nature of the machine’s response to the child’s playing.

Around half the sample preferred to play without the visualization for a number of reasons, i.e. they did not want to look ahead at the screen but rather at their hands (Child 1). Most children who said they preferred to play with the visualization said that they liked that they could see what there were playing. One to two children switched their preference from without visuals to having the screen in front of them when they played during the final interview, when, through discussion with the adult, they reached a better understanding of how their own playing was represented on the screen.

A further theme, which is not related to the visualization but arose from the data, was prominent in the analysis and could be linked back to the CSV results: children’s perception of how they played.

iii. *Reflecting on how they played:* During discussions with children we asked them if they remembered how they played during interaction with the prototype. Their responses were not simply verbal but also indicated/played out the various gestures they had used during sessions rather than actually re-playing on the keyboard particular rhythmic patterns (1 child did do this) or humming any particular melodies/tunes (none of the children did this).

For example, Child 4 tells us “I don’t remember which notes I played because I was looking at the screen”. But later when asked again, she showed us the positioning of her hands on the keyboard throughout her playing saying “I remember this hand was here, the other was here and then I played also in the middle of these two hands”, signifying the pitch or range of notes she used in her playing. She also says when asked where else she played that she made a movement with both hands from the notes further away towards the center of the keyboard (stepping movements with both hands). Child 1 too remembers what he played, through gestures and categorization (he shows hand movements on the keyboard all of which he used in his playing during his sessions: glissando/ using black-white notes, etc.). Children 5 and 6 similarly show they remember the stepping movement they enact in an upward movement on the keyboard when talking about what they played. It is interesting to note that those children that displayed more dense interaction with the machine (see Table 1) are also those that are able to re-enact for us a more embodied type of playing using whole body movements and gestures. This is of course noted in a small corpus of data from 6 children, yet it may indicate that MIROR Impro may in some children encourage particular ways of engaging with music, both musically and kinesthetically.

C. Comparison of Turn-Taking Behaviours with the Computational Music Analysis

Following the results extracted from this analysis, we then proceeded to compare some of these results with those from the Computational Music Analysis.

For this analysis we carried out two separate tasks: The first one was pattern discovery, where we looked for repeated patterns across the children's melodies, and the second one was to cluster all melodies into separate clusters, in order to see whether there exist clear categories.

Here we present part of the analysis of the clustering of the melodies, whereby we took the whole corpus and tried to computationally divide it into two or more classes. The idea behind it was to check whether the visualisation and no visualisation melodies could be automatically separated, and thus being different. For each segment of the children’s melodies, we extracted a set of segmental viewpoints (Conklin and Anagnostopoulou, 2006), that is descriptors for the whole melody rather than note-by-note features such as successions of intervals. The viewpoints we chose for this were: number of notes per melody, duration of melody in milliseconds, melodic arch according to Huron (1996), notes that exist in simultaneities, notes that are single notes. The experiments used the Kmeans algorithm. We see that: The results of the clustering showed that there were two definite clusters in our data, which however do not coincide with the separation of V (visualization) and N (non-visualisation) melodies. The first cluster was much larger than the second one in terms of melody numbers, and contained the shorter melodies. This first cluster consisted of short melodies (31 notes), its average Huron shape was horizontal (which means it does not go up or down), and there were more notes in simultaneities than single. The second cluster consisted of much longer melodies, had a concave Huron shape, and again more notes in simultaneities than single notes.

While the results from the computational music analysis did not produce any significant differences between the visualization and non-visualisation corpus, we then compared these to the results of the levels of turn-taking as extracted from the .CSV files. The .CSV files provided us with the number of answers the system provided for each session (of each child). This indicated to us the density of turn-taking between the child and the MIROR prototype. For our analysis we compared the rates each cluster (1 and 2) appeared in each child’s session with the levels of turn-taking (Table 3). We calculated the rates for the 1st cluster here, as this produced the most noteworthy results in comparison to the turn-taking behavior of the children.

In the first column of Table 3 we can see the number of answers (i.e. the output of the prototype) across each child's sessions while playing with the visualisation screen in front of them. The second column is the number of answers while the child plays without the visualisation screen. The third and fourth columns show the number of melodies across all sessions that belong to the 1st cluster only.

We found that these two clusters do not coincide with the V and N melodies at all. However, when comparing the results with the CSV file and specifically the number of answers for each child, we observe that the children whose levels of interaction with the prototype seem higher are also those whose midi files reveal more melodies belonging to the 1st cluster (i.e. shorter melodies, horizontal Huron shape, more notes in simultaneities than single).

Table 3: Comparison turn-taking overall & music analysis

Child	Turn-taking with V	Turn-taking without V	2nd Cluster with V	2nd Cluster without V
	CSV		Computational MA	
Child 1	34	21	41	67
2	30	24	30	99
3	10	19	18	17
OVER. BOYS	74	64	89	183
4	51	57	82	91
5	52	54	91	91
6	75	73	120	111
OVER. GIRLS	178	184	293	293

As we can see in Table 3, the number of times the 1st cluster appears in each of the children's sessions is not related to their playing with and without the visualisation screen. However, it does seem to be related to the levels of turn-taking, as children with higher levels of turn-taking are also those whose melodies are mostly categorised as belonging to the 1st cluster in this particular type of computational analysis. This makes sense as higher numbers of turn taking might result in shorter melodies. This seems to be the case particularly for girls, as they score consistently high across levels of turn-taking with and without visualisation, and across the number of melodies found that belong to the 1st cluster, again with and without visualisation. For Boys, this picture is less consistent. Both Child 1 & 2 for example did produce a medium level of turn-taking overall as we can see from their .CSV files (in comparison to girls' turn-taking), yet the clustering produced interesting results for the visualisation: A higher number of melodies overall was calculated for both boys when playing without the visualisation screen.

Again however, we must take into account the small sample and number of sessions. It is useful therefore to look at consistency and explore how experience (i.e. the development across sessions) influences the clustering, as the above result for the two boys shows us the overall number from all three sessions. In the final Table below in our analysis we compare as above the results from the .CSV files and the computational music analysis but now in each of the three children's sessions separately (Table 4).

Table 4: Comparison turn-taking across sessions & music analysis

Child	Turn taking with V	Turn taking without V	2nd Cluster with V	2nd Cluster without V
	CSV		Computational MA	
1	19-11-4	15-4-2	28-12-1	33-30-4
2	26-0-4	6-13-5	12-11-7	84-2-13
3	9-1-0	3-16-0	3-15-0	14-3-0
4	23-11-17	25-13-19	29-19-34	38-19-34
5	29-10-13	21-16-17	20-32-20	42-21-28
6	31-14-30	24-30-19	41-52-27	51-20-40

In each box therefore we place the value from the .CSV files and the music analysis for each of the three sessions. For example, in his turn-taking calculation with the visualisation screen, Child 1 scored 19 in his 1st session, 11 in his 2nd session and 4 in his 3rd session. We find that with the visualisation he played 28 melodies belonging to the 1st cluster in his 1st session, 12 in his 2nd and 1 in his 3rd session. Across his three sessions therefore, as his turn-taking decreases, so does the number of melodies belonging to the 1st cluster that he plays. Children 2 and 3 present us with a less clear picture of the relation between the density of turn-taking and the kind of melodies they create using MIROR Impro. A very high number of melodies that Child 2 produces for example in his 1st session without visualisation (84), does not seem related to his turn-taking behaviours as there are only 6 answers from his session without the visualisation as we can see from Table 4. Girls' .CSV files revealed consistently high turn-taking behavior across all three of their sessions. This seems to also coincide with the consistently high number of melodies belonging to the 1st cluster as extracted from the CMA. This result could guide us towards more focused analysis in the pedagogical experiments with regards to the relation between density of turn-taking and the type of melodies that children create with the MI prototype where this behaviour is evident.

IV. DISCUSSION

One of the underlining aims of a social (rather than deterministic) perspective of using music education technology in the classroom should be that children are placed at the center of the analysis, which is consistent with the constructivist learner centered accounts currently favoured in educational technology research (Oliver, 2012). In this exploratory study we sought to incorporate multiple modes of inquiry in investigating the *children's* experience of using the MIROR Impro technology, drawing on multiple methods of data analysis and cross-disciplinary work in order that we may gain a deeper understanding of the ways in which children engage with the technology on both a musical and behavioural level.

The data analysis indicates some connections between particular children's (a) turn-taking behavior and their embodied (gestural) understandings of how they played with the machine and (b) type of musical output and the density of their turn-taking behavior. It points also towards gender differences in the child-machine interaction.

A connection between density of turn-taking behaviours, higher rates in cluster 1 and children's gestural understanding of how they played merits particular attention here. The interviews revealed that the same children who displayed dense turn-taking behaviour either across all three sessions (all the female participants) or in particular sessions (Child 1) also used gesture (instead of only verbal accounts) in attempting to explain to us how they played.

The research findings also point towards gender differences in the ways children talk about their interaction with MIROR Impro as well as in their turn-taking behaviours. All girls in our sample displayed more dense turn-taking behavior (n=362) to boys (n=138) and talked about the interaction using gestural references. Again, in the girls' data set there is consistent density of turn-taking across all three of their sessions as well as higher rates of melodies belonging to the 1st cluster as indicated from the computational music analysis.

The interpersonal dimension that the MIROR technology introduces to children's music-making may in some children encourage particular ways of playing, both musically and kinaesthetically. The results, while coming from a cohort of 8 year-old children, seem related with findings from studies interpreting very young children's musical creativity as 'kinaesthetic gesture' (Cohen, 1980) and as a fusion between musical and social processes (Young, 2003). They signify that children's engagement with this new technology may provide the means for greater experimentation with forms of music-making that defy traditional Western-type models of music learning and introduce new forms of musical participation. In our next round of data collection, the development of a framework in which more systematic connections between turn-taking, musical output and gesture can be explored will be implemented from the initial stages of the research.

V. CONCLUSIONS

Although technology is increasingly being integrated in music education, the absence of pedagogical considerations in the design of the software continues to remain an issue for its practical applicability in the 'real world' of the classroom and with particular groups of users, such as young children. One of the underlining goals of the MIROR Platform is that it is eventually used in the context of early childhood education with teachers who may not be musically trained or with music teachers who may not be able to teach improvisation, now widely acknowledged as a valuable part of music education curricula (Azzara, 2002). Shorter-scale exploratory work by our team has so far been conducted in order that (a) the results are fed back into the development of the technology, and (b) an initial understanding of the issues involved in employing technology in early-childhood education is gained, before proceeding to test the technology in 'real' classroom settings.

Regarding this final point, technology, as a tool teachers have at their disposal, can only fulfill its promise as a powerful contributor to learning if used in developmentally appropriate ways. Employing interactive music systems, such as the MIROR Impro technology in the context of early childhood education brought up a range of issues on this point:

- the particular ways in which young children participate in, understand and engage with music-making require particular theoretical, research and analysis frameworks;
- young children's prior experiences with various technologies can range from near absent to quite high levels of competence, as we discovered in our preliminary work; this requires high degrees of flexibility when working with groups of children and more flexible time-spans of integrating the technology in existing learning and teaching practices;
- the new forms of musical participation that new music technologies often entail, suggests an emphasis towards more adaptive and open classroom environments; this also highlights the need for exploration of the degree to which teacher education programs prepare future generations of music teachers for the theoretical shift that new music technologies could bring about for children's music learning.

ACKNOWLEDGMENT

This study was partly-funded by the EU-ICT Project MIROR (Musical Interaction Relying On Reflexion, www.mirorproject.eu).

REFERENCES

Addessi, A.R. & Pachet, F. (2005) 'Young children confronting the Continuator, an interactive reflective musical system'. *Musicae Scientiae*, Special Issue, 13-39.

Ashley, R. (2009) 'Musical Improvisation'. In S.Hallam, I.Cross & M.Thaut (eds) *The Oxford Handbook of Music Psychology*. Oxford: OUP.

Azzara, C.D. (2002) 'Improvisation'. In R. Colwell & C. Richardson (eds) The New Handbook for Research on Music Teaching and Learning. USA: Oxford University Press.

Bakhtin, M. (1981) 'Discourse in the novel'. In M.Holquist (Ed.) *The Dialogic Imagination: Four Essays by M.M. Bakhtin*. Austin: University of Texas Press.

Brophy, T.S. (2005) 'A longitudinal study of selected characteristics of children's melodic improvisations'. *Journal of Research in Music Education*, 53(3), 120-133.

Burnard, P. (2007) 'Reframing creativity and technology: promoting pedagogic change in music education'. *Journal of Music, Technology and Education*, 1(1), 37-55.

Burnard, P. (2002) 'Investigating children's meaning-making and the emergence of musical interaction in group improvisation'. *British Journal of Music Education*, 19(2), 157-172.

Burnard, P. (1999) 'Bodily intention in children's improvisation and composition'. *Psychology of Music*, 27(2), 159-174.

Cohen, V. (1980) *The Emergence of Musical Gestures in Kindergarten Children*. Unpublished Doctoral Dissertation, University of Illinois, Urbana.

Collins, D. (2005) 'A synthesis process model of creative thinking in music composition'. *Psychology of Music*, 33(2), 193-216.

Dillon, T. (2003) 'Collaborating and creating using music technologies'. *International Journal of Educational Research*, 39(8), 893-97.

Folkestad, G. (2006) 'Formal and informal learning situations or practices vs. formal and informal ways of learning'. *British Journal of Music Education*, 23(2), 135-146.

Gromko, J.E. (1994) Children's invented notations as measures of musical understanding. Psychology of Music, 22 (2), 136-147.

Gromko, J.E. & Russell, C. (2002) Relationships among Young Children's Aural Perception, Listening Condition, and accurate reading of graphic listening maps. Journal of Research in Music Education, 50(4), 333-342.

Kanellopoulos, P. A. (2007) 'Children's early reflections on improvised music-making as the wellspring of musicophilosophical thinking'. *Philosophy of Music Education Review*, 15(2), 119-141.

Kratus, J. (1989) 'A time analysis of the compositional processes used by children ages 7 to 11. *Journal of Research in Music Education*, 37(1), 5-20.

Mills, J. (1997) 'A comparison of the quality of class music teaching in Primary and Secondary Schools in England'. *Bulletin of the Council for Research in Music Education*, 133, 72-6.

Nattiez, J.J. (1975) Fondements d'une semiologie de la musique. Union Generale d' Editions, Paris.

Oliver, M. (2012) 'Learning technology: Theorising the tools we study'. *British Journal of Educational Technology*, Early view, accessed online at: http://onlinelibrary.wiley.com/doi/10.1111/j.1467-8535.2011.01283.x/abstract.

Paananen, P.A. (2007) 'Melodic improvisation at the age of 6-11 years: development of pitch and rhythm. *Musicae Scientiae*, 11(1), 89-119.

Rogoff, B. (1990). Apprenticeship in thinking. New York: Oxford University Press.

Spyrou, S. (2011) 'The limits of children's voices: From authenticity to critical, reflexive representation'. *Childhood*, 18(2), 151-165.

Stern, D. (1985) *The interpersonal world of the infant*. New York: Basic Books.

Tafuri, J. (2006) 'Processes and teaching strategies in musical improvisation with children'. In I.Deliege & G.Wiggins (eds) Musical Creativity: Multidisciplinary Research in Theory and Practice. East Sussex, U.K.: Psychology Himes, A. (Producer), & King, R. (Director). (2005). *Voices in wartime* [Documentary film]. United States: Cinema Libre Studio.

Webster, P. (2002) 'Computer-based technology and music teaching and learning'. In R. Colwell and C.Richardson (eds) *The New Handbook of Research on Music Teaching and Learning*, 416-39. New York: Oxford University Press.

Wertsch, J. (1991) *Voices of the Mind: A Sociocultural Approach to Mediated Action*. Cambridge, MA: Harvard University Press.

Young, S. (2003) 'The interpersonal dimension: a potential source of musical creativity for young children?' *Musicae Scientae*, Special Issue, 175-191.