MODESTUM EURASIA Journal of Mathematics, Science and Technology Education, 2023, 19(7), em2298
ISSN:1305-8223 (online)
OPEN ACCESS Research Paper https://doi.org/10.29333/ejmste/13343

Effects of music technology on language comprehension and self-control in children with developmental delays

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Received 09 February 2023 ▪ Accepted 26 May 2023

Abstract

This study explores musical technology widely used in special music education. Holistic music educational approach for young children (HMEAYC) is a two-decades-old innovative and local education model that combines modern science and technology, multi-sensory equipment, and traditional instruments with creative music in young children of the learning field in Taiwan. The educational benefits of HMEAYC with music technology for young children's learning are increasingly well-documented. The opportunity to experience these benefits should be available to children in preschool education and special music education settings. Thus, we assessed the efficacy of music technology on the growth of language comprehension (LC) and self-control (SC), particularly investigating its effects on young children with developmental delays. The study examined the impact of LC and SC of music technology on young children with developmental delays. We conducted our research in one non-profit early intervention center using a pre-/post-test control group (CG) quasi-experimental research design. Teachers of the experimental group (EG) and CG used the method of the HMEAYC curriculum in the same research process. A qualitative approach was embedded in pre-/post-test CG to learn more about participants' experiences when they accepted the intervention of music technology. Music technology was applied to EG, while CG was not provided any intervention related to equipment. EG included 252 students (64.8%) in total: 98 girls (38.9%) and 154 boys (61.1%). CG had 137 students (35.2%) in total: 65 girls (47.4%) and 72 boys (52.6%). An early childhood behavior evaluation system was used to collect quantitative information. At the same time, pre-tests were given to EG and CG participants before the practical intervention, and post-tests were given after the curriculum was finalized. The results indicated that EG's LC and SC improved significantly compared to CG participants. The analyses of qualitative statistical findings provided positive changes that incorporating technology contributes to evidence in LC and enhanced SC among and between participants. The findings of this music technology study show that learning behavior of young children with developmental delays significantly improves with the inclusion of technology. Our findings match the results of previous studies. Consequently, the development of the research makes acceptable assumptions that implementing music technology in the educational learning environment will enable young children with developmental delays to integrate into the field of school education more positively and actively.

Keywords: music technology, holistic music educational approach for young children, young Children with developmental delay, language comprehension, self-control

INTRODUCTION

More attention should be paid to the education and resources of people with disabilities (Buescher et al., 2014). The caretakers for children with disabilities are mainly concerned with diversified education and special music education because children with disabilities lag behind their participants of the same age in cognition, movement, language, and social or self-care (Lee & Liu, 2021; Standley, 2008). Moreover, children with

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Contribution to the literature

- One intriguing aspect of the Holistic Music Educational Approach for Young Children (HMEAYC) is its incorporation of "musical technology widely utilized in specialized music education."
- Our research findings encompass a comprehensive examination of the impact of music technology on comprehension and self-control among children experiencing developmental delays.
- The educational advantages of integrating the HMEAYC with music technology to enhance learning outcomes for young children with developmental delays have garnered growing validation. In this study, we specifically evaluated the effectiveness of music technology by assessing the growth of language comprehension and self-control, with a primary focus on its effects on the population of young children facing developmental delays.

disabilities' training are affected by body functions, so it is slower to respond to external stimuli (Perry, 2003). Evidence has demonstrated that musical activities could assist with early learning development in children with developmental delays (Bazyk et al., 2010; Gonyou-Brown, 2016; Johnels et al., 2021). In nearly two decades, research has revealed that music could be influential in cognitive science, psychology, and neuroscience (Moreno, 2009; Salimpoor et al., 2015); music also has shown evidence-based assistance with early language development (Herholz & Zatorre, 2012; Peretz & Zatorre, 2005), as well as positive effects on personal and social development (Gruhn, 2002; Hallam, 2010; Ilari, 2016; Kraus & White-Schwoch, 2017). Technology has played an auxiliary role in music and could be used with various participants across the learning process. Technology integrated into music could continue to promote learning, and there is potential for the growth of its applications to music education and music therapy (Francois et al., 2015; Jones, 2015).

Music Curriculum Models in Taiwan

Holistic music educational approach for young children (HMEAYC) approach has been implemented in Taiwan for over 20 years. It is currently popularized as suitable for music best practice education for preschool children or children with disabilities. As a model, HMEAYC encourages practice and experience in the early childhood music field and shows that music is an excellent medium for all young children's learning development (Lee, 2015). As an experiential education model, it combines the concept of whole-child music education with the theoretical foundation of preschool education and special music education development, hoping to manifest the vision and thinking of whole-child music education in preschool education. The preschool environment represents an obtainable source field, making opportunities to integrate music technology into education for young children with disabilities easily accessible. The direct demonstration results of using music as a medium to improve the communication of young children with disabilities are emerging year by year, which proves that music intermediary, a non-verbal tool, could help participants with a learning need joining-up copulation learning and enhance the children with disabilities of the learning ability. As young children become proficient communicators through nonverbal, they become active members of the learning environment and build verbal language on top of this already functional communicational ability (Vaiouli & Andreou, 2018), such as using music with technology instrument interventions as effective strategies for developing language and verbal communication abilities in young children with communication disorders. Interaction with musical instruments and sounds and engagement in physical activity could bolster the social skills of developmentally delayed preschool children.

Many studies have reported that singing, rhymes, musical games, and instruments are all effective ways for young children to learn (Nigg, 2017; Salimpoor et al., 2015). Focusing on establishing particular musical elements, such as rhythmic and movement performance and music technology, may help meet rehabilitation and treatment needs. Another evidence-based finding regarding the issue of young children with developmental delays was that processing information visually could be done best through music (Lee & Ho, 2017, 2018; Lee & Li, 2016). There is evidence that music could be a therapy for language comprehension (LC) and phonology (Goswami et al., 2013) and, in particular, enhanced expression or interaction with communication (Dada et al., 2013; Emms & Gardner, 2010; Tallal & Gaab, 2006). If music curriculums could add activities according to individual needs, the effect may be even more significant (Duckworth et al., 2014).

Current Study on Young Children With Developmental Delays

For the past few years, using assistive technology to improve participants' language learning with young children with disabilities has also been encouraged and supported by research (Drager et al., 2006; Nasritdinova, 2021). Music improves hand-eye coordination, sustained attention, and communication (Woodruff Carr et al., 2014). In addition, music could also be used through audio-visual interactive oral training (Lim & Draper, 2011), communication aids, and picture or drawing aids

(Mayer-Benarous et al., 2021). HMEAYC highlights learners' autonomous and spontaneous learning. HMEAYC model has five theoretical characteristics: whole-child music education aims at whole-person education; a learning process focuses on child-centered experiential education, education, and active learning; the whole-child music education learning field emphasizes experiential learning; and the curriculum design of whole-child music education is diverse.

HMEAYC is a positive enhancement curriculum model, and its effects on the learning levels of young children with developmental delays were investigated by monitoring the population participating in musical activities. Children with developmental delays learn better via rhythmic and movement performance, demonstrating that music with technology is an effective learning medium. This study focuses on music with technology instrument intervention to participate in LC and self-control (SC) learning effectiveness music with technology is mainly based on the auxiliary and medium strategy that combines various teaching materials and technology based on each curriculum activity. The teachers in the study assessed the student's learning and the frequency with which they participated in learning activities with children with developmental delays. We addressed one research question: do opportunities to engage in LC and SC improve for children with disabilities when music technology is employed? Despite the technology integration into the visual, auditory, and kinesthetic music rates across the implemented field, conclusions have often been assumed to recommend music learning for young children's development stages. Including music technology in music, research might help further validate these extrapolated recommendations. Thus, in the present study, we focused on the question, "How is involvement in music technology related to LC and SC outcomes in a school-aged sample of young children with disabilities?" More precisely, it was hypothesized that the ability of LC and SC of experimental group (EG) participants, who were young children with developmental delays in the music technology intervention, would increase learning effectiveness significantly compared with control group (CG) of young children with developmental delays who did not participate.

METHODOLOGY

Research Design

This study was designed with a pre-/post-test CG quasi-experimental research method design. It aimed to obtain statistical and quantitative data from the participants. Since it is challenging to assign participants randomly into different groups in a teaching environment, one early childhood children with disabilities institution located in a non–profit early intervention center was chosen. The 389 young children with developmental delays (98 girls and 154 boys) participated. The children's chronological ages were between 36 and 72 months at the time each child began participating in baseline sessions. Different participant groups were selected as EG and CG to reduce the interaction between the groups during the experimental intervention process and increase internal validity. All the participants from one group were used in the situations of EG, and the other group were determined to be CG, respectively. The music technology embedded into HMEAYC approach was utilized with EG for 40 minutes for each word for 16 weeks. Primarily CG was not provided with any imaging technology.

Research Sample

The quantitative study was conducted to measure in an educational institution in Central Taiwan in a non–profit early intervention center that frequently received young children with progression through predictable developmental phases of varying degrees that possess early disability identification or (and) certification, such as young children with developmental delay. All participants were between 36 and 72 months of age with developmental delays in the group. Mills and Gay (2019) proposed that different participants be selected as EG and CG to reduce the interaction between the groups during the experimental intervention process and increase internal validity.

The author provides teaching for successfully integrating technology into the young children's classroom field and outlines a series of HMEAYC approach music activities for the study. The research design used a structured assessment form to examine participants' experiences in EG and CG through quantitative data. In EG, 98 girls (38.9%) and 154 boys (61.1%), for 252 participants. In CG, there were 65 girls (47.4%) and 72 boys (52.6%), for a total of 137 participants. All the participants in the other group were selected as CG, the same as EG of children with developmental delay. The research designed a structured assessment form to examine participants' experiences in EG and CG through quantitative data. Before beginning the study, symposiums were provided for participants' parents, and informed consent was obtained because young children are protected groups and minors. The pre-tests were given to EG and CG participants before the practical intervention, and post-tests were given after the curriculum was finalized. Analyses of pre- to post-course changes included data from 389 young children with developmental delay.

Procedure

The independent variable is the variable the experimenter manipulates or changes who was HMEAYC, an interdisciplinary education method for

young children in Taiwan. The curriculum design of whole-child music education allows the integration of technology, multi-sensory equipment, and traditional musical instruments. The independent variable of the research was HMEAYC approach, an interdisciplinary education method for young children in Taiwan. The curriculum design of whole-child music education allows the integration of technology equipment, multi-sensory equipment, and traditional musical instruments. The curriculum consists of the walking on the line, hello song, attendance song, singing time, musical game, musical storytelling, musical movement, relaxation time, and goodbye song, which could be expanded individually or flexibly reduced. As the independent variable of this study, HMEAYC curriculum was applied for 40 minutes over 16 weeks to young children with developmental delays. Participants of EG and CG engaged with HMEAYC curriculum in the same classroom.

SBASP scale was used in this study to help teachers assess participants' learning effectiveness of LC and SC. LC focuses on young children with developmental delay's communication and interaction skills with others, focusing on expressing opinions, understanding others' ideas, and practical communication skills. SC focuses on young children with developmental delays demonstrating positive behavior abilities related to SC. Scale items such as during the curriculum activity, they will try to show movement by themselves without the teacher's reminder. In contrast, by conducting HMEAYC curriculum sessions, many technological aids were used for EG, which will be exposed to music technology during the practical intervention, such as the circular set of musical lights and the talking cube. CG only participated in HMEAYC curriculum sessions and did not engage while being used with any music technology aids during the practical intervention.

Instruments

Social behavior assessment system for preschool scale

The purpose of learning behavior observation is to measure social ability. The early childhood social behavior evaluation system (SBASP) is a standard tool for understanding social behavior. SBASP offers the teacher scoring scale and the parent scoring scale. The purpose of learning behavior observation is to measure social ability. The current Chinese version of the scale was translated by Tsai and Wu (2016) to apply an adaptability assessment for young children in Taiwan. In this study, social behavior was measured using the Chinese version of the evaluation of SBASP through a structured interview with the primary teachers. Critical areas measured by SBASP include social competence and problem behavior. The social competence scale measures three theoretical dimensions (SC, interpersonal interaction, and language learning ability) to provide comprehensive measures of the social behavior of children aged 34 to 72 months. The social competence questionnaires show an internal consistency, indicating the scales' good reliability. SBASP consists of theories and a multi-dimensional scale used in social behavior assessments. The content includes social ability and problem behavior so schools can evaluate young children (four-six years old). SBASP's social competence subscales "LC and SC" were used in this study to help teachers assess participants' learning effectiveness. We used the subscale to obtain a measurement from participants contributing to LC and SC rating. The study requested that teachers provide SBASP evaluations of their young children with developmental delays before and after the curriculum.

Table 1. Model factor analysis of participants' sample unstandardized estimates

Participant sample	Estimate	SE	CR	p
LC_6<---LC	1.037	0.045	22.826	***
LC_7<---LC	1.096	0.049	22.219	***
LC_5<---LC	0.994	0.048	20.549	***
LC_4<---LC	0.625	0.039	15.924	***
LC_3<---LC	0.783	0.044	17.816	***
LC_2<---LC	0.735	0.041	17.909	***
LC_1<---LC	1.000			
SC_6<---SC	1.065	0.044	24.029	***
SC_7<---SC	1.129	0.045	25.225	***
SC_8<---SC	1.062	0.044	24.290	***
SC_5<---SC	1.118	0.044	25.315	***
SC_4<---SC	1.028	0.042	24.205	***
SC_3<---SC	1.001	0.044	22.727	***
SC_2<---SC	1.089	0.045	24.363	***
SC_1<---SC	1.000			

Note. ***p<.001 & SE: Standard error

Table 1 shows model factor analysis of the unstandardized parameter estimates for the performance of 389 participants (252 boys and 137 girls). LC has seven questions, and SC has eight questions. All items are social behavior assessment subscales, while the articles show that they could be discussed separately in these two dimensions. The items under LC and SC dimensions were tested with confirmatory factor analysis to prove the hypothesis model.

The factor model of SBASP scale, which is a type of structural equation modeling that is thought to be theoretically evaluated in two subscales, was confirmed between measurement models (χ^2=352.62, df=89, χ^2/df=3.96, NFI=.94, CFI=.95, IFI=.95, RFI=.92, GFI=.94, AGFI=.87, and RMSEA=.087). The alpha coefficient of Cronbach's were .93, .96, and .96 for LC, SC, and the full scale, respectively. The model statistics results could be reported as a mediocre fit. This model is significant at the conventional level, which specifies a group-invariant factor pattern. The estimated mean LC score has an estimated variance of 0.754 for participants or a standard deviation (SD) of about 0.074; SC has an estimated variance of 0.723 for participants or an SD of about 0.067.

Figure 1. HMEAYC using music technology: circular set of musical lights (left) & talking cube (right) (The photos were taken by the research team of the author, Liza Lee)

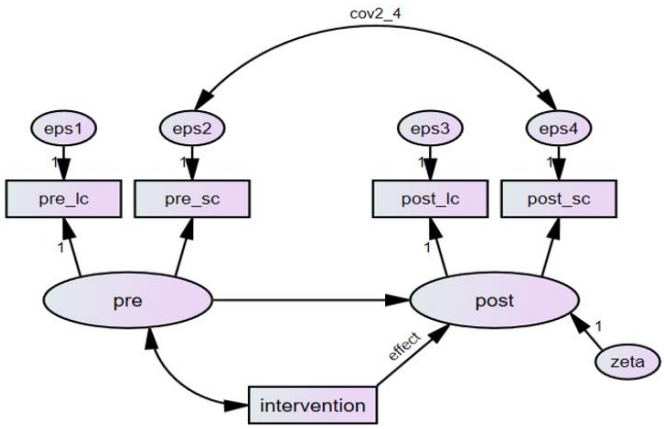

Figure 2. Equation model of structural hypothesis (Source: Authors' own elaboration)

Holistic music educational approach for young children

HMEAYC is an interdisciplinary integration curriculum of education with therapy for young children. It has been considered the best practice education for localized music curriculums for over 20 years in Taiwan (Lee, 2016). HMEAYC design integrates multi-sensory equipment and traditional musical instruments. It can appropriately incorporate technological aids, such as a circular set of musical lights, a musical jumping pad, a talking cube, etc. (**Figure 1**).

HMEAYC approach consists of music activities and a curriculum for young children with developmental delays. Both participant groups implemented HMEAYC in the same field of school education. EG was exposed to music technology during the practical intervention, while CG only participated in the music curriculum and did not touch any technology.

Data Collection and Observer Reliability Analysis

This results analysis used structural equation modeling to analyze the significance of intervention in the experience effect. The research hypothesis of reliable covariates has received attention in the study.

Figure 2 demonstrates an alternative to an analysis of covariance frequently used in experimental methods to reduce the result of pre-existing differences among intervention groups. This statistical analysis could increase accuracy in assessment intervention effects. In contrast, the variables in the model of hypothesis and EG and CG were defined with the intervention variable. LC and SC pre-test measures were the observed variables of LC and SC. LC and SC post-test measurements were clearly defined as the observed variables of LC and SC post-test measurements. The pre- and post-test measurements were indicated as latent variables in the model of the hypothesis.

The participants subjected to the experimental procedure in the intervention variable were coded 1, and the participants in CG were coded 0. It was assumed that LC and SC pre-test was the positive predictive value of LC and SC post-test, and there was a positive relationship with the intervention variable. As the experimental procedure was thought to increase LC and SC levels of the participants, it was assumed that the positive regression of a significant coefficient would succeed. SPSS 21 and Amos 21 are software used to analyze the model. All the data from the teachers of young children with developmental delays were collected through participant statements in the study. To Check coding consistency, the researcher coded responses in two instances two weeks apart. Intra-rater reliability was determined as .90.

RESULTS

In the study, music technology's effect on LC and SC of the participants was analyzed following the model proposed by Bentler and Woodward (1979). They used valid results by preventing measurement errors from randomly choosing the group participants. At the same time, the assumptions for the covariance analysis and the binary relationship between the variables before the analysis were analyzed. Firstly, the correlations between the intervention and LC and SC pre- and post-test measurements were calculated by applying assessment. After that, the variables' means, and SDs were computed (**Table 2**).

The relationship between EG and CG' LC and SC pre- and post-test scores were analyzed using Pearson's product-moment correlation coefficient, a measure of the linear relationship between LC and SC variables. The descriptions of correlations between LC pre- and post-test were .72, SC pre- and post-test were .63, and all correlations were significant.

While 1.28 and .88 point increases were observed in LC and SC pre- and post-test measurements, reactive aggression was determined without separating the participants according to their average scores. In addition, the descriptive statistics in LC and SC pre- and post-test measurements per group were analyzed separately (**Table 2**). For EG, the average scores from the pre- to post-test measurements increased by 1.07 (10.65-

Table 2. Correlations between pre- & post-test scores on the participants

Variable	LC pre-test	LC post-test	SC pre-test	SC post-test	Mean	SD	n
LC pre-test					9.42	4.33	389
LC post-test	.72*				10.70	5.04	389
SC pre-test	.86*	.64*			8.41	3.45	389
SC post-test	.74*	.94*	.63*		9.29	3.85	389

Note. *p<.05

Table 3. Descriptive statistics of pre- & post-test measurements per groups

Groups	Scales	Tests	n	Mean	SD
Experimental group	post_LC	Pre-test	252	9.58	4.34
		Post-test	252	10.65	4.70
	pre_SC	Pre-test	252	8.46	3.38
		Post-test	252	9.44	3.89
Control group	post_LC	Pre-test	137	9.12	4.31
		Post-test	137	10.80	5.64
	pre_SC	Pre-test	137	8.33	3.60
		Post-test	137	9.01	3.79

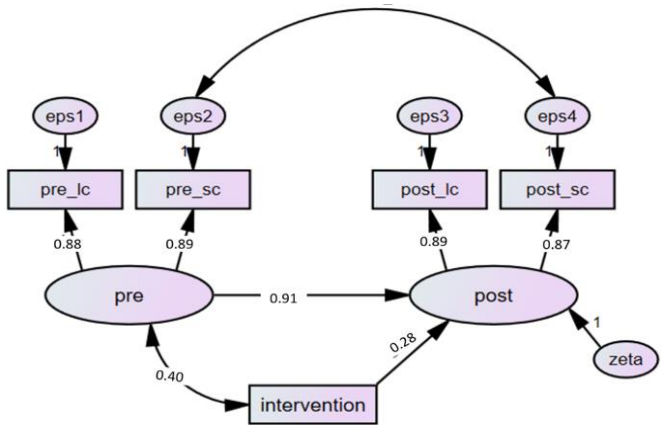

Figure 3. Covariance model of effect of music technology on LC & SC (Source: Authors' own elaboration)

9.58) points in LC and .98 (9.44-8.46) points in SC. Focusing on CG, the post-test measurements demonstrated a 1.68 (10.80-9.12) average point increase in LC and a .68 (9.01-8.33) increase in SC.

The following covariance analysis was conducted in the structural equation modeling to observe the effects of music technology on young children with developmental delays in LC and SC (**Table 3**). The data show the adding error covariance between the pre- and post-test of LC and SC. The significant chi-square values and acceptable Model fit indices were obtained by assessment (χ^2=33.215, df=3, p=.00, χ2/df=2.46, GFI=.99, CFI=.99, RFI=.98, IFI=.99, TLI=.99, and RMSEA=.004).

As shown in **Figure 3**, all parameter estimates were statistically significant because of the covariance analysis. While LC (.88) and SC (.89) pre-tests were sufficient to establish LC and SC pre-test, LC (.89) and SC (.87) post-test were sufficient to establish LC and SC post-test, such as latent variables. It was found that LC and SC pre-test as a latent variable could positively predict LC and SC post-test measurement (.91) as well as

Table 4. Regression weights (RW) of parameters of covariance (C) & variances (V) in model

RW/C/V	Estimate	SE	CR	p
Post<---Pre	0.951	0.058	16.508	***
Post<---Intervention	3.444	0.467	7.367	***
Pre LC<---Pre	1			
Pre SC<---Pre	0.977	0.055	17.782	***
Pre LC<---Post	1			
Pre SC<---Post	0.985	0.055	17.874	***
Pre<---Intervention	0.396	0.217	1.823	
Eps2<--->Eps4	0			
Pre	34.636	4.342	7.977	***
Intervention	0.249	0.024	10.296	***
Zeta	1.034	1.257	0.823	0.411
Eps1	9.867	1.416	6.97	***
Eps2	8.962	1.322	6.778	***
Eps3	10.166	1.454	6.991	***
Eps4	11.416	1.517	7.526	***

Note. ***p<.001 & SE: Standard error

the associated intervention at a significant degree (.40). From the intervention to LC and SC post-test, it was found that technology positively affected significance (.28) (see **Table 4** and **Figure 3**).

DISCUSSION AND CONCLUSIONS

The study suggests that music technology effectively contributed to participants' LC and SC skills. The model fit was adequate after adding error covariances between the pre- and post-test in the hypothesis model for participants. This indicates that music technology incorporated into HMEAYC significantly increased scores for young children with developmental delays. We saw an increase in EG's LC and SC in post-test scores.

The post-test results were higher for young children with disabilities in CG than the pre-test results when the groups were compared. Significant improvements were observed in LC and SC in EG owing to the intervention (the music technology). In the end, all measurements showed a significant relationship between comprehension and SC scores. The results of this study demonstrated that more activity using music technology related to educational practice is needed (Nigg, 2017; Salimpoor et al., 2015). At the same time, attention is given to methods and strategies to make more music technology accessible to various learners (Herholz & Zatorre, 2012; Moreno, 2009; Peretz & Zatorre, 2005). We concluded that the significant relationships between LC and SC in the pre- and post-test are consistent with

previous research (Lee & Ho, 2017, 2018; Lee & Li, 2016). From a LC perspective, it was established that music technology effectively improved LC and promoted higher statistically significant scores in EG than in CG. The results of this study resemble the findings of prior research about music technology in language learning literature (Goswami et al., 2013).

As participants understand the group rule, they demonstrate group-normative behavior in musical activities (Dada et al., 2013; Emms & Gardner, 2010; Tallal & Gaab, 2006). Furthermore, from a SC perspective, it was determined that as in previous studies (Duckworth et al., 2014) in which participants' behavior improved, the increase in SC scores was enhanced by music technology, indicating that the participation of young children with developmental delays in music activities was productive (Mayer-Benarous et al., 2021). Since physical movement is present in studies of musical training, students gain concentration and control over impulses with music technology, which leads to confidence and more positive behavior. The study shows that music is a medium for young children's learning development (Drager et al., 2006; Nasritdinova, 2021). The participants indicated that the music technology led to a positive change in learning behaviors, increased curriculum engagement, and prompted positive changes in interactive communication (Lim & Draper, 2011; Mayer-Benarous et al., 2021; Woodruff Carr et al., 2014). Based on the study results, we conclude that music technology could likely contribute to evidence of LC and SC development in young children with developmental delays. It is speculated that there are individual differences in the independent learning performance of young children with disabilities.

In some cases, it is necessary to consider the degree of impairment and participation of children with disabilities, and it is also essential to adjust the curriculum content according to individual needs. To this end, the music technology research could provide a necessary reference for preschool special education resources in Taiwan.

Author contributions: LL & H-JH: methodology, writing-original draft preparation, & writing-review & editing; **LL:** conceptualization, validation, resources, supervision, & project administration; & **H-JH:** visualization. All authors have agreed with the results and conclusions.

Funding: No funding source is reported for this study.

Ethical statement: Authors stated that the research was conducted in strict compliance with academic ethics and research ethics. The complete experimental research process is informed to all parents of young children, and all parents have signed the informed consent form.

Declaration of interest: No conflict of interest is declared by authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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