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Exploring the relation between teacher autonomy support and children's musical creativity

A complexity approach to studying interaction in primary school music lessons

Eine explorative Studie zum Zusammenhang von Autonomieförderung und musikalischer Kreativität bei Kindern

Ein Komplexitätsansatz zur Untersuchung der Interaktion im Musikunterricht in der Grundschule

Zusammenfassung

Im Musikunterricht der Grundschule stellt sich die Frage, wie Lehrkräfte die musikalische Kreativität von Schüler:innen fördern können. Zur Beantwortung dieser Frage muss die Interaktion zwischen Lehrkräften und Schüler:innen während des kreativen Prozesses im natürlichen Umfeld des Grundschulmusikunterrichts untersucht werden. Sechsundzwanzig Musikstunden von dreizehn Lehrerkräften und ihren Klassen aus sieben niederländischen Schulen wurden aufgezeichnet, um die Beziehung zwischen der Autonomieunterstützung durch die Lehrkräfte und dem divergenten und konvergenten Denken und Handeln der Schüler:innen zu untersuchen. Quantitative sequentielle Analyse und thematische Analyse wurden kombiniert, um diese Beziehung zu untersuchen. Als Theoretischer Rahmen diente die Complex Dynamic Systems Theory sowie die Enaction Theory. Im Gegensatz zur klassischen Korrelationsanalyse konzentriert sich die sequentielle Analyse auf die Dynamik und damit auf die zeitliche Beziehung in der Interaktion im Klassenzimmer. Die Ergebnisse zeigen, dass Autonomieunterstützung vor allem auf niedrigerem Niveau angeboten wurde. Vor allem im kreativen Unterricht führt eine höhere Autonomieunterstützung eher zu höherem divergenten Denken und Handeln der Schüler:innen. Für konvergentes Denken und Handeln waren die Ergebnisse weniger deutlich. Aus den Ergebnissen lässt sich ableiten, dass die (Forschungs-)Arbeit im Bereich der Musikpädagogik *von Maßnahmen profitieren könnte, die darauf abzielen, die Autonomieunterstützung im Musikunterricht der Grundschule zu erhöhen.*

Schlagwörter: *Autonomieförderung, Kreativität, Konvergentes Denken, Divergentes Denken, Musikpädagogik*

Summary
In primary music education a key question is what teachers can do to stimulate students' musical creativity. For the answer, delving into teacher-student interaction during the creative processes in the naturalistic setting of primary music lessons is required. Twenty-six music lessons from thirteen teachers and their classes of seven Dutch schools were recorded to explore the relation between teachers' autonomy support and students' divergent and convergent thought & action. Quantitative sequential analysis and thematic analysis were combined to examine this relation, using a framework offered by Complex Dynamic Systems theory and Enaction theory. In contrast to classical correlational analysis, sequential analysis focuses on the dynamics, and thus on the temporal relation in classroom interaction. The results show that mostly lower-level autonomy support was offered. Especially in creative lessons, higher-level autonomy support is more likely to lead to higher-level student divergent thought and action. For convergent thought and action, the results were less conclusive. An implication of the findings is that (research into) music education could benefit from interventions aimed at enhancing autonomy support in primary school music.

Keywords: *Autonomy support, musical creativity, convergent thinking, divergent thinking, music education.*

1. Introduction

Process-oriented research into children's creativity in primary education is scarce (Kupers et al., 2019). Musical creativity in education is often measured as a static construct, aimed at the measurement levels of the person or product using standardized tests (e.g., Kiehn, 2003; Koutsoupidou & Hargreaves, 2009; Webster, 1994) sometimes combining product-based assessment with an observational approach (Barbot & Lubart, 2012). A process-oriented approach focuses on the moment-to-moment interaction between students and their natural environment on the micro-level, including its relationship with development on the macro-level. The interest in process-based approaches is growing (e.g., Burnard & Younker, 2008; Kupers & Van Dijk, 2020; MacDonald et al, 2002) and new conceptions of creativity, such as the Complex Dynamic System's model of creativity (Kupers et al., 2019), the notion of Musical Creativities in real world practices (Burnard, 2012) and the Radical Embodied Cognitive Science approach to creativity (Malinin, 2019) are emerging. Taking a Complex Dynamic Systems (CDS) and Enactive perspective, this study contributes to this development through empirical research into musical creativity in the naturalistic setting of primary school music lessons. The aim is to explore how thirteen middle grade primary school teachers supported their students' autonomy in music lessons and how this affected their creative thought & action.

1.1 A CDS perspective on musical creativity

How would we term the activity of a child hitting and scratching his plate with his knife and fork while closely listening to the sounds he produces? We would probably say he is playing with his cutlery, but we could also conclude that the child is learning to engage with sound by exploring, thinking, and using his senses. Is he fascinated by the sounds themselves or by the sound patterns he creates? We can't know this from the outside, but we can observe the creative behaviour the child shows as an indicator of how he's learning. In a dynamic interpretation of learning, the child is going through an iterative pattern of coupled states of perception and action, continuously affecting each other. Studying such state-to-state changes in music lessons enriches our insights into development of musical creativity. In education social components intermingle with material, embodied and cognitive aspects which jointly affect learning. This section addresses what this entails for emergence of musical creativity from a CDS-perspective.

The development of a skill such as in musical creativity, can grow out of a multitude of interacting components in children and within their environment (Csikszentmihalyi, 1988; Gagné, 1985; Sawyer, 2006 and 2012; Simonton, 2000b; Steenbeek & Van Geert, 2013). Students' potential can be observed in their talented activity, which is allowed to emerge if the conditions are right (Steenbeek et al., 2011). In line with the idea of mini-c creativity, defined as the novel and personally meaningful interpretation of experiences, actions and events (Beghetto & Kaufman, 2007), every child has creative potential (Runco & Sternberg, 2004). Musical creativity in education is an iterative process, self-organizing within teacher-student interaction. Components, such as teacher support, motivation or fine motoric skills are continuously shaping each other and jointly form a dynamic whole. Such cyclical interactions are fundamental for complex dynamic systems. Consequently, processes such as musical creativity, fluctuate; they are highly dynamic (Fischer & Bidell, 2006; Steenbeek & Van Geert, 2013). The dynamics in learning processes are co-regulated by the teacher and the students as a system. Think for instance of a group improvisation in which a groove is clearly audible at some point, to disappear a bit later. The teacher can respond by asking the students to listen closely to each other. This enables them to respond timely and appropriately to each other's sound. Such a small intervention may result in more concentration and adaptivity and a steadier groove. When students are engaged in creative musical activity like this, with appropriate support of a teacher, eliciting and scaffolding students' potentials, the creative process can take on the form of a positive learning spiral (Kupers et al., 2017; Van Geert & Steenbeek, 2005).

Recurrent domain-relevant experiences are needed for creative achievement (Simonton, 2000a). In primary education this can take place on the micro-timescale in varying creative musical tasks in music lessons, but also over time in music lessons throughout the school year(s). This way the system affords itself to develop. However, the opposite is also true, if music lessons aren't allowed a structural place in the curriculum, students can't accumulate enough meaningful domain-relevant experiences, eventually leading to stagnation.

In conclusion, the onset of students' musical creativity always starts in the here-and-now of the micro-processes in music lessons, which are themselves also embedded in, and originate from long-term development.

1.2 Enaction of musical creativity in primary school music lessons

From a CDS-Enactive perspective (musical) creativity isn't located somewhere in the learner's mind, but is enacted within the system (Malinin, 2019; Van der Schyff et al., 2018) in the interaction of the teacher, students, and task. Through the interrelated notions of enaction, embodiment, extendedness, and embeddedness, the Enactive (4E) framework (Varela et al., 1991; see for a more recent account e.g., De Jaegher & Di Paolo, 2007; Di Paolo, 2019; Menary, 2010; Newen et al., 2018) explains thinking and learning as embodied processes of agents interacting with their social and material environment to make sense of the content of those interactions. In this section these terms will be addressed and illustrated using a practical example.

Enaction denotes embodied action (Varela et al., 1991, p. 172) and specifies how agents/learners co-adapt their actions to their (social) environment through recurrent sensorimotor patterns of action and perception. In our example a teacher may ask a range of questions to elicit ideas and group improvisation with percussion instruments. Through their recurrent meaningful interactions, teacher and students jointly enact musical creativity, and ever more complex sound strings may emerge.

Musical creativity obviously involves a key role for bodily processes (e.g., Bremmer & Nijs, 2020; Leman et al, 2018; Van der Schyff et al., 2018). In their creative process, in addition to verbal interaction, teacher and students jointly shape their musical reality through embodied musical action, rather than expressing some pre-existing musical reality already represented in their minds.

From an ecological perspective (Gibson, 1986) musical creativity enacted like this, is embedded in the concrete context at hand (Clarke, 2005; Krueger, 2014). The environment and its affordances, in this case percussion instruments and teacher support, provide the effectivities for action (Fischer, 1980) and musical sensemaking (Van der Schyff et al, 2016).

Musical cognition arising this way isn't restricted to individuals but is extended to their social and physical environment (e.g., Krueger, 2014; Menary, 2010). To achieve and sustain a groove all students need to act as one. Musical sensemaking emerges from interaction with musical instruments and other participants, clearly extending musical creativity past individual students.

Enacted musical creativity lasts as long as the activity lasts, and dissolves to reappear again in new tasks. Thelen and Smith (1994) have termed this 'soft-assembly' of skill. It's the dynamic product of earlier developed abilities, task properties and the affordances in the environment.

In our example, the teacher and students need to collaborate as a system, both affording and constraining each other, to enact musical creativity. But, as Di Paolo (2019) asks, if such dynamic processes transcend individuality like this, at what point then does the agent (student) and his learning process appear? The answer to this question is related to autonomy (Dumas et al, 2014; Varela et al, 1991). In the Enactive view it's the acts themselves which make up a sensorimotor agent (Di Paolo, 2019, p. 217). Through their activity, agents accommodate to their environment and self-sustain or, in other words, self-individuate as autonomous sense-making beings (Di Paolo, 2019). Hence, for students to develop musical creativity, teachers need to support their autonomy to engage them in creative activity. Teachers themselves need to engage in concrete music-pedagogical activity to self-sustain and develop as autonomous pedagogical agents in music lessons.

1.3 Autonomy support and musical creativity

Relatively informal classroom environments are conducive to creativity (Amabile, 1996). In informal settings students are more likely to experience autonomy. Self Determination Theory defines the psychological need for autonomy in learners in the sense that one's actions emanate from oneself and are one's own (Deci & Ryan, 1987, p. 1025). Autonomous learners, however, can still depend on help from a teacher (Ryan & Deci, 2006). Autonomy support (AS) is essential for learners (Cheon et al, 2020; Deci & Ryan, 2000; Reeve, 1998; Vansteenkiste et al., 2005) and has been associated with increased engagement, agency, and motivation (Deci & Ryan, 2000; Reeve et al, 2004). Moreover, AS is considered an important pedagogical strategy to stimulate creativity (Amabile, 1983; Deci & Ryan, 1987; Koestner et al., 1984; Núñez & León, 2015; Reeve, 2006). Conversely, low autonomy-supportive teaching is associated with lack of initiation and with conformity and imitation (Koestner et al., 1984; Deci & Ryan, 1987).

Teachers' motivating style strongly influences student engagement and achievement in music education (Renwick & Reeve, 2012). How teachers communicate assignments to students, allowing them choice of instruments or space to slightly adapt an assignment, can considerably contribute to engagement. An autonomy-supportive teaching style is student-centered by nature. However, a teacher-centered music pedagogy implies "a hierarchical and asymmetric classroom interaction pattern" (McPherson et al, 2018, p. 182). Teacher-centered pedagogies involve an unbalance in teacher-student interaction (Creech, & Hallam, 2011) and are less associated with positive student outcomes compared to child-centered approaches (Creech & Gaunt, 2013).

Traditionally music education isn't associated much with AS and teaching practices tend to be rather prescriptive (Evans, 2015). Recent research revealed that AS enhanced motivation and achievement in instrumental music learning (McPhail, 2013; Kupers et al, 2017). In primary music education, AS was found to correlate with improved situational student interest (Roberts, 2015), motivation and flow (Hinnersmann et al, 2020). Research into young children's musical games in informal settings stresses the benefit of children exercising self-supportive autonomy (e.g., Marsh, 1995; Campbell, 2010).

Most research into need satisfaction and AS in music education is aimed at instrumental music learning (e.g., Kupers, 2017), secondary education (e.g., Freer & Evans, 2018) or conservatoire students (e.g., Bonneville-Roussy et al., 2020). Studies into AS in primary school music education seem to be scarce. More research is needed to gain insight into how AS affects primary school students' musical creativity. Intervention studies have shown that teachers can learn to provide AS (e.g., Cheon et al., 2018; Reeve, 1998; Van Vondel et al, 2016; Wetzels, 2015). Stefanou et al (2004) distinguish between offering organizational, procedural, and cognitive AS. Firstly, by offering space and giving students a say in classroom organization, teachers can provide organizational AS (Stefanou et al, 2004). Secondly, offering choice in materials (Deci & Ryan, 1987), involving students in task approach and how to present results is part of procedural AS. Thirdly, and crucial for learning, questioning, and giving students space for exploration enhances students' cognitive autonomy (Stefanou et al., 2004). In music education this includes active listening and observing students' activity in order to adaptively coach students when needed (Green 2006; Reeve & Jang, 2006; Cheon et al, 2020). Giving positive feedback on student's autonomous activity when appropriate, nurtures perceived competence (Deci & Ryan, 2000). External pressure undermines autonomy and reduces intrinsic motivation (Deci & Ryan, 2000;

Skinner & Belmont, 1993). Constraints can best be communicated by providing effectance-relevant information (Koestner et al., 1984), i.e., giving reasons and information for improvement.

1.4 A CDS-Enactive approach to students' musical creativity

Creativity requires two complementary functions: originality and appropriateness (Sawyer, 2012). Originality (novelty) refers to something new or unique. Appropriateness refers to usefulness. Original ideas, products, knowledge, or skills should also be useful to be valued as creative (Campbell, 1960; Cropley, 2006) although, in the context of music (education), usefulness and appropriateness are off course relative notions. Originality is linked to divergent thinking and appropriateness to convergent thinking (Guilford, 1957). Divergent and convergent processes form a domain-general component of creativity, although their application most likely is rather domain-specific.

Webster (2002) (re)defined creative thinking in music as "a dynamic process of alternation between convergent and divergent thinking, moving in stages over time, enabled by certain skills (both innate and learned), and by certain conditions, all resulting in a final product" (Webster, 2002, p. 11).[1] Divergent thinking is described as imaginative skills, exploring many possibilities of musical expression that are new to the creator. Convergent thinking focuses on manipulation of musical material, which requires a more analytical process of aesthetic evaluation and fine-tuning that can be both conscious and subconscious (Webster, 2002, p. 13). In the context of education, appropriateness in convergent thinking in music thus involves an application of ideas, that makes sense musically.

A CDS-Enactive account of musical creativity pushes the action component more to the foreground since processes such as imagination and evaluation are elicited by embodied action and vice versa. In the CDS-Enactive view divergent and convergent processes are dynamically coupled (Engstrøm & Kelso, 2008). They aren't merely based on thought, or representation in the mind, but also on action in perception (Noë, 2013). In music making, thought, action and perception coincide. Musical meaning arises only in the context of active exploration. Therefore, from a CDS-Enactive standpoint we use the terms Divergent and Convergent Thought & Action (DTA and CTA) in music.

Creative processes are inherently dynamic. Dynamic Skill Theory (Fischer & Bidell, 2006) explains development as a non-linear dynamic process, emerging in person-context interaction. A core principle is that people can be active at varying cognitive and sensorimotor skill levels, distinguishing between Reflexes, Sensory Motor Actions, Representations, Abstractions, and Principles (Fischer & Bidell, 2006). It provides a domain-independent scale for portraying (intra-individual) variability in the complexity of human expression (such as music) on varying time-scales; real-time during lessons, depending on context such as teacher support or task difficulty, but also over the course of multiple lessons or several months. The variability which Dynamic Skill Theory aims to capture, is seen as a potential indicator of transitions to new levels and a driving force of development (Van Geert & Van Dijk, 2002, p. 341).

[1] Building on Guilfords work, Webster, in his 1990 model of creative thinking in music, explicitly linked the features flexibility, extensiveness and originality to divergent thinking. In the 2002 model these aspects aren't addressed anymore.

To define DTA and CTA in Music in the context of music education we draw on the work of Webster, Burnard and other music education researchers, and on work of creativity scholars like Simonton and Csikszentmihalyi. Our CDS-Enactive framework defines DTA and CTA as complementary embodied functions driving meaningful enactment of musical creativity in dynamic creative processes which are embedded in the educational environment, and which extend beyond individual students. The two functions are constrained by immediate and past experiences. Through moment-to-moment interactions of students with their environment, a key component of which is autonomy support, they afford transformation. DTA in music involves imagination and exploration of musical ideas to accomplish creative tasks, the result of which is, to varying degrees, original to students. CTA refers to an application of ideas, varying in rhythmical and melodic complexity, that is musically meaningful.

1.5 The present study

The present study aims to explore primary school teachers' Autonomy Support and students' Divergent and Convergent Thought & Action during music lessons, as well as the relation between teachers' AS and students' DTA and CTA. Possible intra- and interindividual differences in teachers' AS may shed light on how AS affects students' musical creativity. The following research questions are addressed:

1. a. To what extent do middle grade primary school teachers offer AS in music lessons?
   b. Are there differences between teachers, lessons, musical domains, and grades in offering AS?
2. a. To what extent do students show DTA and CTA in music lessons?
   b. Are there differences in students' musical creativity between classes, lessons, musical domains, and grades?
3. a. What is the temporal relation between teachers' level of AS and students' immediate response in level of DTA and CTA?
   b. What is this relation in the domain of lessons with creative tasks?

2. Method

2.1 Participants

Thirteen teachers and their students (296, age range 6-10) in the middle grades of seven primary schools in the Northern Netherlands participated in the study (see table 1). The teachers were recruited via e-mail, flyers and personal meetings. Most of the teachers wanted to improve the quality of their music lessons and participated because they were offered a brief coaching trajectory in a follow-up study. All the teachers were female (age range: 29-54, average: 37,2). Their average teaching experience was 12 years (range 4-33). All the teachers expressed having affinity with music. Most of them didn't feel very experienced in music teaching. Six teachers had followed formal music education in the past and three teachers were still involved in music making privately. Five teachers had or still played an instrument. Five teachers had been or were still engaged in singing. Ten teachers had access to a method for primary music education.

Three methods facilitated using the digital board and one was a hard-copy method including the use of CDs. Five teachers felt the method at their school was outdated.

Table 1, Characteristics participants.

Teacher	Age group	Grade	Number Students	Musically active	Experience music teaching Scale 1 – 5 (self-report)
1	30-39	3, 4, 5	27	No	1
2	30-39	3	25	No	2
3	50-59	4	20	Past	4
4	30-39	4	22	Yes	2
5	30-39	3	25	Yes	3
6	50-59	5	23	Past	3
7	20-29	4	19	No	3
8	30-39	3	23	No	2
9	30-39	6	24	Past	3
10	40-49	4	22	No	1
11	30-39	4	23	Yes	1
12	30-39	5	25	Past	1
13	20-29	5	18	Past	2

The study was approved by the Ethical Committee of Psychology of the University of Groningen. Teachers and parents of the students gave active consent for video recording of the lessons. Students whose parents didn't give consent, could still participate in the lessons but were kept out of the angle of the camera's.

2.2 Procedure

The study initially included seventeen teachers, but due to Covid19 the data collection was interrupted and eventually thirteen teachers completed the trajectory. The data collection consisted of video recordings. Teachers and their students were observed during two consecutive music lessons, resulting in 26 recordings in total. The music lessons were recorded in two subsequent weeks or with one week in-between. The lessons were video-taped from two perspectives. One camera was aimed at the teacher while the other was aimed at students whose parents gave informed consent. The teachers were asked to teach music as they usually did. The choice of lesson content and design was left entirely to the teacher as the aim was to get more insight into the current state of affairs in primary school music lessons.

Data

Lesson recordings were used for analyzing the classroom interaction. Lessons varied in length (mean 36, range 18-46 minutes) and in design. The lesson design most frequently observed was whole-group lessons. Also, some small-group lessons with a whole-group introduction and ending were given.

From each lesson (n=26) four fragments, containing a substantial amount of content-related verbal and musical student-teacher interaction, were selected. Two three-minute fragments were captured of the core of the lesson in which the teacher and students were actively working on the task. From the introduction and from the end of the lesson two-minute fragments were taken.

In lessons without a clear introduction or ending, the introduction fragment started with the first activity/subtask of the lesson as and the last fragment finished with the last subtask.

The lesson fragments were categorized (table 2) according to musical domain following the classification of the Dutch Association for Curriculum Development (Stichting Leerplan Ontwikkeling), slightly expanded using one extra category 'Creating music', consisting of activities such as composing and improvising.

Table 2: Distribution fragments across lessons.

Musical domain	Fragments
Listening & discussing music	22
Meaningful sound & subjects	5
Singing	18
Moving to music	4
Musical play	35
Creating music	16
Registration of music	4
Total	104

Variables and measurement

Coding schemes were developed for verbal Autonomy Support (AS, table 3), Convergent Thought & Action (CTA, table 4) and Divergent Thought & Action (DTA, table 5). The schemes were developed both theory-driven and data-driven through lesson observation. Coding was done by the first author and trained independent coders using the software Mediacoder 2017 (Bos, Boels & Steenbeek, 2017). Test-coding was done to improve inter-rater reliability. For teachers' AS the percentage of agreement was 81% (Cohen's Kappa .76). For students' DTA the agreement was 84% (Cohen's Kappa .78) and for students' CTA it was 78% (Cohen's Kappa .70) so that the inter-rater reliability can be considered substantial.

Coding procedure

In the selected fragments all teacher-student interaction was coded in three steps. First the teacher's verbal utterances and students' verbal and musical utterances were determined, based on turn-taking. New teacher turns were coded for teacher-initiated utterances, responses to student expression, turning from one student to another, or to the whole group. A frequent sequence consisted of giving feedback or repeating a student's answer, followed by a (follow-up) question or giving a new student turn. Such sequences were coded as two consecutive teacher turns.
For students the unit of analysis was the group. Individual verbal and musical expressions as well as whole-group and sub-group musical expressions were marked as student turns. Secondly the timeslots where there was no verbal or musical expression were marked. The third step was to code verbal teacher expression for AS and verbal and musical student expression for CTA and DTA

Coding scheme for teacher AS:

Teacher expression was coded using an ordinal scale, adapted from the openness-scale (Meindertsma et al., 2014; Oliveira, 2010), ranging from lower-level AS such as instructing to higher-level AS such as student-centered questioning and encouragement (table 3). Off-topic non-task related utterances were coded as Other, for example a side remark to an intern in the classroom. The focus was on the most optimal teacher behaviour in each turn. This implied for instance that a turn coded as Teacher-centered question (3) could also contain Information (2).

Table 3: Teachers' Verbal Autonomy Support in music lessons (AS).

Level description	**Example**	**Code**
Lower-level AS		
Low		
Stop	*Stop please.*	1
Instruction	*Repeat after me.*	2
Medium		
Information	*When you play the drum, you need to hit it in the middle for a nice sound.*	3
Teacher-centered question	*Was this music fast or slow?*	4
Higher-level AS		
Medium-High		
General autonomy supportive Student-centered question	*Can you come choose an instrument?*	5
Cognitive autonomy supportive student-centered question	*What do you think is the difference between a melody and a rhythm?*	6
High		
Stimulating autonomy supportive student-centered question	*How does a ray of sun sound? Could you let us hear?*	7
Encouragement to elicit exploration and risk-taking*	*You can do it, could you try it again? How could you do it differently?*	8
Other		O

Note: * positive feedback after play is coded as information

Coding scheme for student DTA:

DTA for students was coded on an ordinal scale (table 5) based on Brophy's Music generative skill sequence (2005) similar to scales used in previous research into composing in education (MacDonald et al, 2002; Kupers et al., 2018; Kupers & Van Dijk, 2020). The scale deals with novelty, compared to previous student expression within the same lesson, and ranges from non-substantial task-related student expression (1) and lower-level DTA like imitation (2) to higher-level DTA like originality (5).

Table 4: Students' Divergent Thought & Action in Music (DTA).

Level description	**Example**	***Code***
Pre/Non-creative: Task-related expressions without ideas	*When is it my turn?*	*1*
Lower-level DTA		
Imitation: Repeating a former idea	Copy other student: rain with finger tops	*2*
Consequence: Responding to given cues	Loud rain with finger tops when umbrella is up, and rain drops *when it's down*	*3*
Higher-level DTA		
Variation: Changing a former idea	Ticking with fingernails	*4*
Originality: Expressing a new idea	Stamp feet for thunder	*5*
Other	*My finger hurts*	O

Coding scheme for student CTA:

The domain-independent scale of Dynamic Skill theory (Fischer & Bidell, 2006) was used for coding hierarchical levels of students' CTA in music (table 4). This scale was applied successfully in recent research in other domains (e.g., Meindertsma et al, 2012; Wetzels et al, 2015) and can be used to track how individuals can move up-and-down the scale, and in doing so can repeatedly rebuild a skill (Van Geert & Fischer, 2009, p. 332). The scale can be used to portray change on multiple timescales, within one lesson and over the course of several lessons or months. It consists of growth cycles, called tiers, of increasing complexity: Reflexes, Sensory Motor Actions (SMA), Representations (R), Abstractions (A) and Principles (Fischer & Bidell, 2006). The scale was tailored to the nature of the tasks in primary music lessons and ranges from relatively simple musical expression on the Single Sensorimotor Actions level (1) to more complex musical patterns on the Abstractional Systems' level (9). Each tier includes three recurrent levels: the Single units, Mapping (relations between single units) and Systems level (relations between mappings) (Fischer & Bidell, 2006). The Systems level is a transitional level which reorganizes the system and prepares the next growth cycle, e.g., from Sensory Motor Systems to the single level of the Representations tier.

Table 5: Students' Convergent Thought & Action (CTA).

Level description	**Example**	**Code**
Sensorimotor Actions		
Single: Engagement with instruments, materials	Student rubs a woodblock with a mallet	1
Mapping: Exploration of sound	Student actively hits a woodblock in two or more ways	2
Systems: Ability to play the intended sound	Student repeatedly hits a woodblock the same way	3
Representations		
Single: Appearance of some pattern in students' sound making	Student hits a woodblock with some regularity	4
Mapping: Exploration of two or more variations	Student explores two or more patterns on a woodblock but not always steady and with pauses	5
Systems: Ability to play patterns	Student plays the same pattern on a woodblock for second time	6
Abstractions		
Single: Appearance of more complex and sustained rhythmic phrases	Student explores playing a longer string on a woodblock	7
Mapping: Exploration of more complex phrases	Student explores two or more strings, combining patterns	8
Systems: Ability to play more complex rhythmic phrases	Student convincingly plays a longer string for the second time	9
Other	Using a boomwhacker as a sword	O

2.3 Data analysis

For research question 1 and 2 data was prepared for analysis by making timeseries for each variable, resulting in continuous data with a code for every second of the selected ten minutes per lesson. The procedure for analyzing AS, CTA and DTA for research questions 1 and 2 was similar. For research question 3 the original coded data based on turn-taking was used.

Research question 1a and 2a:

Descriptive techniques were used to examine the extent to which teachers showed AS and students performed musical creativity. First the frequencies and means for teachers' AS, and for students' DTA and CTA were calculated. Secondly the proportions per lesson, teacher and on the group level were calculated. The distributions were plotted in graphs showing the proportions in percentages for individual teachers per level for each variable.

Research question 1b and 2b:

First, the means for the four lesson fragments for each lesson, for the lessons and for teachers were calculated. Secondly, Monte Carlo simulations were performed using the means for lesson fragments for AS, DTA and CTA to examine whether any significant differences existed between teachers. Non-parametric testing such as Monte Carlo permutation analysis (Todman & Dugard, 2001) can be done when data isn't normally distributed and with limited numbers of participants. The Monte Carlo procedure consisted of shuffling the empirical dataset 10.000 times to test whether the differences in the empirical data were due to chance, or whether they differed significantly from the differences found in the permutated data, i.e., the p-value is smaller than 0.05. This was done by calculating the difference scores of teacher/class means for AS, DTA and CTA compared to the group mean, and testing these scores against the difference scores in the shuffled data to see whether the differences were higher than could be expected based on chance.

Secondly, a non-parametric Kruskal-Wallis test for comparing two or more independent samples was done in SPSS Statistics (Version 28) using coded data, to test interindividual differences in teacher AS between classes and between lessons. This rank test can be done if the dependent variable is at least measured at the ordinal level and its distribution for the groups compared, have similar shapes. Because the latter assumption wasn't met for DTA and CTA (see distribution shapes results section), we didn't use this test for these variables. For AS a post-hoc test was done to find out which of the 78 possible teacher comparisons between the 13 teachers produced significant differences. The same was done for comparing lessons. A Bonferroni correction for this post-hoc test with adjusted significance levels was done. This correction reckons with the number of comparisons made in the test and adjusts the p-value by dividing it by this number. The resulting cut-off p-values help minimizing the chance of falsely rejecting the null-hypothesis.

Lastly, Chi-square tests were performed in SPSS using coded data to examine the differences in frequencies for AS, DTA and CTA between classes, lessons, musical domains and primary grades. A Chi-square test can be used to test the probability of distributions being due to chance or if differences in level can be associated with another variable. This way it was examined if differences could be associated with teachers, lesson, domain and grade. The degree of association was interpreted with Cramer's V (Cohen, 1988 as cited in Sun et al, 2010) with a value of Cramer's V within the range of .07–.21 indicating a small association, a value within the range of .21–.35 indicating a moderate association, and a value larger than .35 indicating a strong association.

Analyses for student DTA were done on creative expressions (level 2-4) only, leaving out non-substantial expressions.

Research question 3a and 3b:

To study how musical creativity arises from interactions between students and teachers, the temporal relation between teachers' level of AS and students' immediate response in terms of their level of DTA and CTA was examined. Sequential analysis, i.e., analysis of transitions from teacher AS to student DTA and CTA, was performed on data for individual classes and for all lessons combined. For research question 3b transition analysis was conducted on a subset, consisting of creative lessons, containing elements of composition and improvisation, to make a comparison with the original dataset for all music lessons.

Transition analysis can be used to analyze the transitions in classroom interaction in turn-taking from teacher AS utterances to student DTA and CTA utterances or actions/play. Each utterance/action of either the teacher or a student represents a state. Therefore, classroom interaction consists of a long sequence of state-to-state transitions. These interaction sequences can be analyzed with transition analysis, using the coded expressions/actions and their timepoints for teacher AS and students' DTA and CTA as input. This was done separately for AS and DTA, and AS and CTA. Using this method, transition diagrams can be constructed. A transition diagram is a visualization of the conditional probabilities of these state-to-state transitions (Van Geert, 2014) and in the present study show how often particular levels of teacher AS were followed by particular levels of DTA or CTA. The diagrams were used to identify general patterns in teacher-student interaction, to examine differences between classes, and between music lessons in general and a subset of lessons with creative assignments.

First, the coded turns for teachers' levels of AS and for students' levels of DTA or CTA for the two lessons per teacher were combined in Excel taking the timepoints in seconds of the expressions into account (see figure 1). Next, the codes for the teacher and student utterances (transitions) were aligned by moving the second column with the student utterances one row up. Adjacent teacher AS codes and student codes for DTA or CTA thus reflected the immediate transitions from teacher AS to student DTA or CTA.

Class	Lesson	Time	AS	DTA	DTA 1 row up
1	2	530	**3**		**3**
1	2	533		3	
1	2	566	3		
1	2	569	**7**		**1**
1	2	580		1	
1	2	588	**7**		**5**
1	2	591		5	3
1	2	592		3	

Figure 1: Example of a coded sequence of transitions for Autonomy Support (column AS) and Divergent Thinking and Acting (column DTA) in Excel. The coded turns for DTA are moved up one row (column DTA 1 row up), resulting in a sequence of AS-DTA transitions (framed and bold).

Secondly, transition matrices were constructed in Excel using a macro that summarized the transitions for each coded level in teacher expression to each coded level of student utterances. Using this procedure, for each individual class as well as on the group-level, transition matrices were constructed.

The third step was to calculate the frequency and probability for each category. For example, how often lower-level AS was followed by lower-level DTA, divided by the total amount of transitions from lower-level AS to all DTA levels. This resulted in 2 X 3 categories for immediate transitions from lower- and higher-level teacher AS to DTA (see example transition diagram figure 2). For student CTA, transitions from lower- and higher-level teacher AS to Sensorimotor Actions, Representations and Abstractions led to 2 X 3 categories. This was done for clarity reasons to reduce the interaction dynamics in fewer possible states and transition probabilities.

Lastly, from the matrices, transition diagrams were constructed, representing all possible immediate state-to-state transitions from teacher AS to student DTA and CTA. In a transition diagram (see figure 2) circles represent possible states, and arrows represent the transitions with their probabilities from one state to another (teacher-student) or to itself, e.g., a teacher utterance being followed by a new teacher utterance. The width of the arrows represents the magnitude of the probabilities. In the diagram displayed in figure 2, the highest probability for transitions from teacher AS to student DTA is depicted by a bold arrow from lower-level teacher AS to lower-level student DTA (p(t) = .78). This means that 78% of lower-level AS teacher utterances was followed by lower-level student DTA. This way, all percentages for transitions from lower-level AS add up to 1. Dashed arrows depict non-significant probabilities (p > .05). For a correct interpretation of the results reported in the diagram, it should be noticed that, for instance, the probabilities for transitions from Lower-level AS to all levels of DTA add up to 1, thus reflecting the sum of all transitions from Lower-level AS. The probabilities reported in the running text are denoted as P(t).

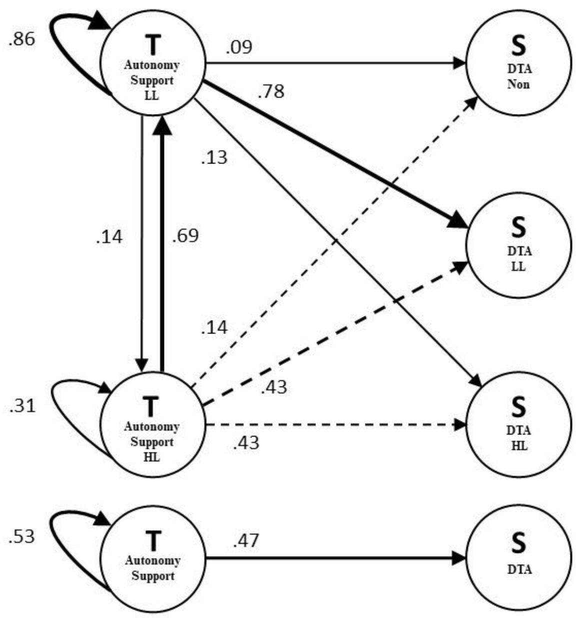

Figure 2: Example of transition diagram with transitions to student DTA for a single class.
AS = Teacher Autonomy Support. DTA = Student Divergent Thought & Action. LL = Lower-level. HL = Higher-level.
The lower part of the diagram depicts the proportion of Teacher AS transitions to self in relation to the proportion of Teacher AS transitions to Student DTA, regardless of AS/DTA-level.

The next step was to perform Monte Carlo permutation analysis (for an explanation see data analysis for research question 1b and 2b) to test whether the calculated probabilities for the teacher-student transitions were significant. The last step was to calculate the difference scores between the probabilities for lower-level and higher-level teacher AS to lower-level and higher-level DTA, and to the CTA levels SMA, Representations and Abstractions. The difference scores were tested in order to identify whether the extent of the differences found, differed significantly from what can be expected based on chance.

In addition, for research question 3b, to deepen our understanding of the relation between lower- and higher level AS and students' DTA and CTA, thematic analysis (Clarke & Braun, 2006) was used for analyzing two contrasting episodes from a lesson in which children used notation to create short music pieces. Thematic analysis is a method for systematically identifying, analyzing, and interpreting patterns of meaning ('themes') within qualitative data (Clarke & Braun, 2006). The six-step procedure for thematic analysis was followed based on a concept-driven approach (Gibbs, 2007), with a focus on finding patterns related to teachers' AS and student DTA and CTA in music. An episode with overall more higher-level and an episode with more lower-level CTA and DTA were selected, to examine the impact of different levels of AS offered. Both episodes contained verbal and musical interaction and were comparable in length. The thematic descriptions and their interpretation were discussed with the second and third author.

3. Results

3.1 Verbal Autonomy Support

To what extent do middle grade primary school teachers offer AS in music lessons? (RQ 1a)

Teacher expression in seconds per lesson ranged from 216-473 (mean 362). Figure 3 displays the distribution for individual teachers and shows that they offered predominantly Medium AS (78%) over the two lessons by giving information and asking teacher-centered questions. Higher-level AS is clearly offered less frequently (11%) compared to lower-level AS (89%), i.e., low and medium AS. Nine teachers (e.g., 12 and 13) did show the highest AS level although some of them very rarely.

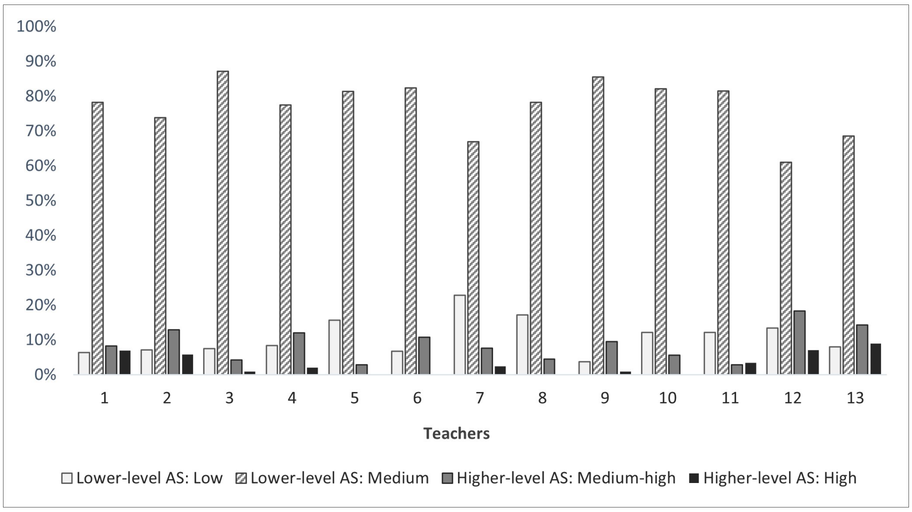

Figure 3: Distributions Autonomy support individual teachers

Are there differences between teachers, lessons, lesson types and grades in offering AS? (RQ 1B)

Means: Table 6 shows the difference scores of teacher means, as compared to the group mean for teacher AS (M = 3.49, SD = .61). Significant differences existed for 4 teachers, and teacher means ranged from 3.15 to 3.81. Overall teachers offered mostly medium AS. The Kruskal Wallis test (H = 356,55, df = 12, $p < .05$) and post-hoc test showed that differences existed for 48 of the 78 pairs compared, revealing one cluster of 6 teachers with lower mean ranking and several small partly overlapping clusters with slightly increasing ranking. For comparing AS between all 26 lessons separately, significant differences existed between lessons in 72 cases (H = 524,14, df =25, $p < .05$).

Table 6: Results Monte Carlo analysis Autonomy support

	Autonomy Support	
Teacher	Diff.	SD
1	.23	.82
2	.23	.40
3	- .35**	.26
4	- .01	.71
5	- .34**	.31
6	- .13	.32
7	.25	.57
8	- .24*	.22
9	-.24*	.44
10	.22	.06
11	- .17	.45
12	.32	.55
13	.22	.56

Note. Diff. = Difference with group mean
* p < .05
** p < .01

Distributions: Table 7 shows significant differences ($p <.001$) in terms of distributions, with a moderate association in terms of Cramer's V for lesson. This means that the level of AS provided by teachers differed moderately between lessons. For teacher, musical domain and grade weak associations were found, suggesting that the extent of AS provided did not differ much between teachers and between the musical domains addressed in lessons such as singing or moving to music. Furthermore, it did not depend much on students' age.

Table 7: Associations Autonomy support with teacher, lesson, domain and grade

	AS	
	χ2 (df) *p*	V
Teacher	800.19, df = 36, *p* <.001	.17
Lesson	1437.45, df = 75, *p* <.001	.23
Domain	260.18, df = 3, *p* <.001	.17
Grade	238.6, df = 3, *p* <.001	.10

3.2 Musical creativity

To what extent do students show DTA and CTA in music lessons? (RQ 2a)

DTA

For students' Divergent Thought & Action (DTA), the mean total amount of verbal and musical expression in seconds per lesson was 213 (range 92 - 328). Figure 4 shows that student expression partly consisted of non-substantial utterances without expression of creative ideas. The distributions for individual classes show that the majority of students' verbal and musical expression (63% on group level) consisted of lower-level DTA such as imitating ideas of the teacher or other students, or acting on the consequence level, for instance by playing along with a song on the digital board. Proportions for non-substantial expressions (16%) and Higher-level DTA (21%) were much lower. The distributions per class show peaks up to nearly 70% for lower-level DTA. Quite some variation in shapes of the distributions per class exist. On average students showed limited higher- level DTA in performance of variation (12%) and originality (9%) although differences existed. For instance, classes 3 and 9 had minimal proportions of higher-level DTA. A third of the classes (2, 4, 12 and 13) had relatively elevated proportions of higher-level DTA, although lower-level DTA dominated for these classes too.

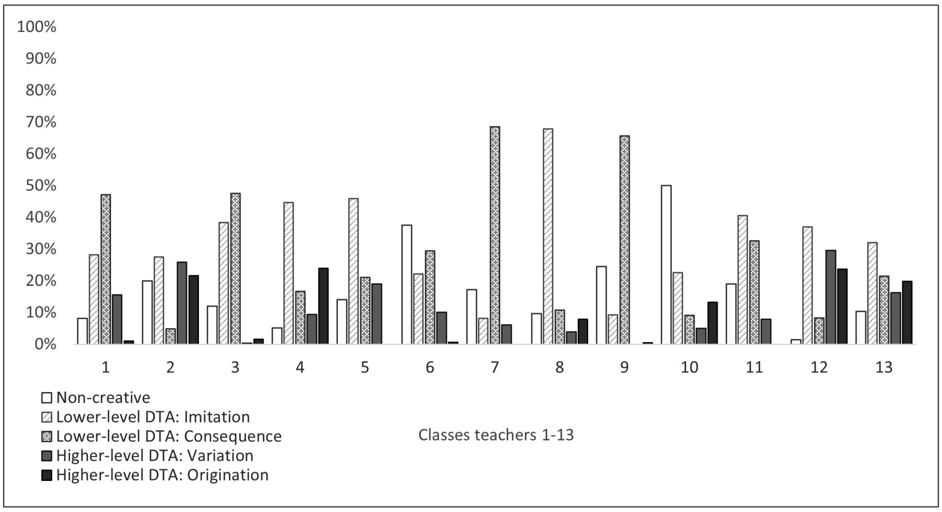

Figure 4: Distributions DTA individual school classes

CTA

The mean total amount of musical expression in seconds for student's Convergent Thought & Action (CTA) per lesson was 158 (range 56 - 480). In percentages this is 26% per class per lesson (class range 8-42%).

Figure 5 depicts the CTA distributions for individual classes. It stands out that the vast majority (66% on group level) of student CTA falls within the Representations category. Proportions for the Sensori-Motor Actions (24%) and Abstractions (10%) categories are much lower. For individual classes, proportions differed much for the Representations category (range 50-100%). Between classes, quite some variation in the shape of the distributions is visible. Large differences exist for the Sensory-Motor Actions tier (range 2-80%). Seven classes had expressions in the Abstractions tier (range 4-34%).

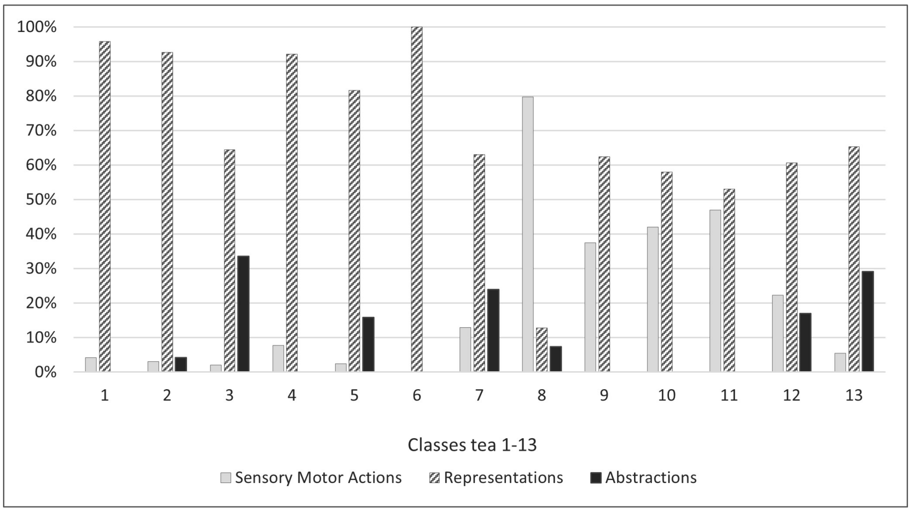

Figure 5: Distributions CTA individual school classes

Are there differences in students' musical creativity between classes, lessons, grades and musical domains? (RQ2B)

DTA Means

Table 8 shows the difference scores for class means compared to the DTA group mean (M = 2.49, SD = .85). Four classes showed significant differences. Class means ranged from 1.92 to 3.36 showing mostly imitation and consequence in student musical expression. Lesson means (n=26) ranged from 1.33 to 3.59.

CTA Means

Table 8 shows that difference scores for CTA class means, compared to the group mean (M= 4.05, SD = 2.32), were significant for four classes. CTA for most classes is situated in the Representations tier, representing student play of relatively simple musical pattern. Class means for CTA range between 2.7 and 5.7 at the Sensori-Motor Actions and Representations levels. Lesson means ranged from 1.7 to 7.3.

Table 8: Results Monte Carlo analyses DTA and CTA

	DTA		CTA	
Class	Diff.	SD	Diff.	SD
1	.14	.79	.99	.66
2	.70**	.93	.69	.48
3	-.14	.28	-.03	2.79
4	.29	.80	-.69	1.50
5	-.29	.90	.10	1.86
6	-.57*	.74	-.85	2.52
7	.03	.76	.34	1.55
8	-.36	.68	-1.39*	2.04
9	-.15	.42	-1.39*	1.40
10	-.65*	.82	-.45	.04
11	-.19	.59	-.40	.68
12	.87**	.66	1.47*	1.14
13	.33	.87	1.62*	1.03

Note. Diff. = Difference with group mean
* $p < .05$
** $p < .01$

DTA Distributions

Regarding student DTA table 9 shows that relatively strong associations were found for individual classes/teachers, lessons and domains, reflected in Cramer's V. This means that classes of some teachers tended to show higher levels of DTA compared to others, but that this was also associated to the lesson and domain that was taught. For grade the association was moderate, with more imitation for the third and fourth grade, and more consequence for the fifth and sixth grade. Both lower and higher grades had similar proportions of around 20% for variation and origination.

CTA Distributions

For CTA, a strong association with teacher/class and lesson was observed (table 9), entailing that classes of some teachers tended to achieve higher levels of CTA compared to others but that this was also differed depending on the lesson taught. Moderate asssociations were found for musical domain and grade. The difference in grade was visible with regard to the seven classes reaching the Abstractions level. However, even in grade-3 classes students could sometimes achieve the Abstractions tier, though less often.

Table 9: Results differences DTA and CTA between classes, lessons, domains and grades

	χ2 (df)	V
DTA		
Class	2006.93, df = 36, *p* <.01	.38
Lesson	3038.7, df = 75, p < .01	.47
Domain	633.53, df =3, *p* < .01	.37
Grade	1016.33, df = 9, *p* < .01	.29
CTA		
Class	2087.32, df = 24, *p* < .01	.50
Lesson	3573.92, df = 50, *p* < .01	.66
Domain	394.85, df = 2, *p* < .01	.31
Grade	317.08, df = 6, *p* < .01	.21

3.3 The relation between teacher AS and students' DTA and CTA

To investigate how musical creativity emerges from interactions between students and teachers, we examined the immediate transitions in teachers' and students' turn-taking. In this regard, a relevant question is whether a difference exists in student performance in DTA and CTA, after teachers have offered lower-level AS, compared to higher-level AS. To this end, firstly the quantitative findings of the transition analyses are presented. Secondly, the explorative findings of the thematic analyses of two contrasting fragments are discussed in relation to the coded levels of verbal AS, DTA and CTA.

What is the temporal relation between teachers' level of AS and students' immediate response in level of DTA and CTA? (RQ3a)

Table 10 summarizes the probabilities for the transitions in all lessons combined, from teacher AS to student DTA and CTA, as well as teacher AS transitions to self, i.e., when a teacher follows up on her own utterance, e.g., by answering her own question. For transitions to CTA, it stands out that the results yielded no significant probabilities. For DTA the probability for transitions from higher-level AS to higher-level DTA was significantly higher than expected based on chance. This was also true for transitions from lower-level AS to lower-level DTA. The probability from higher-level DTA to lower-level DTA was significantly lower than expected based on chance.

Regarding the question about the differences in student performance when distinguishing between lower- and higher-level AS, the difference scores (last row table 10) for self-transitions as well as for transitions to both lower and higher-level DTA are significantly higher than can be expected based on mere chance. To further interpret these probabilities, next the transition diagram for students' DTA is discussed.

Table 10: Probabilities transitions for all classes and lessons (N=26)

	AS[a]		DTA[b]			CTA[c]		
	LL	HL	Non	LL	HL	SMA	Rep.	Ab.
Level AS								
LL AS	.86**	.14**	.31**	.56**	.13	.29	.66	.05
HL AS	.69**	.31**	.32**	.38*	.30**	.22	.69	.09
Difference	.16**	.16**	.01	.18**	.17**	.07	.03	.04

Note. n = 26 lessons. LL = Lower-level. HL = Higher-level.
[a] Transitions to self (AS-AS).
[b] Transitions from teacher AS to student DTA on the non-substantial level, lower-level DTA and higher-level DTA.
c Transitions from teacher AS to student CTA on the Sensori-Motor Actions (SMA), Representations (Rep) and Abstractions level (Ab).
* $p < .05$ ** $p < .01$

Transitions from teacher AS to student DTA

Figure 6 depicts the immediate transitions from teacher AS to student DTA and their probabilities. The lower part of figure 6 displays the balance in teacher-student interaction regardless of level of AS and DTA. The probability for teacher AS to self (p(t) = .53) is quite equal to the probability for transitions to student DTA (p(t) = .47). This means that 53% of the teacher utterances was followed by new teacher utterances and 47% were followed by student utterances.

From all AS-self transitions, the bold arrow top left in figure 6, indicates a high probability for self-transitions to lower-level AS (p(t) = .86), which may come as no surprise, given the overall high frequency of lower-level AS.

From AS-DTA transitions, the highest probability, marked with a bold arrow, can be noticed for transitions from lower-level AS to lower-level DTA (p(t) = .56), i.e., imitation (2) and consequence (3). This is significantly higher (also see difference score table 10) compared to transitions from higher-level AS to lower-level DTA (p(t) = .38). A third of the transitions from higher-level AS led to higher-level DTA (p(t) = .30), significantly more than expected based on chance. Transitions from lower-level AS to the highest DTA-level however, yielded no significant probability. Hence, when students demonstrated variation and originality in musical play, teachers had significantly more often offered higher-level AS, even though higher-level AS just like lower-level AS more frequently led to lower-level DTA. Lastly, both from lower- and higher-level AS, a third of the transitions led to non-substantial student DTA expressions, top right.

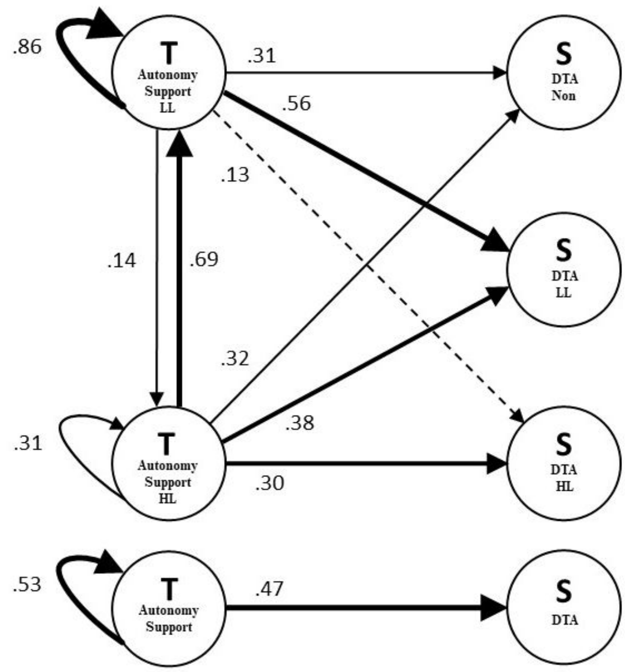

Figure 6: Transition diagram with transitions and probabilities from Teacher Autonomy Support (AS) to Student Divergent Thought & Action (DTA) in all lessons (n = 26). Note. T = Teacher, S = Student. LL = Lower-level. HL = Higher-level. The lower diagram summarizes the upper diagram in terms of the total proportion of teacher AS transitions to self, in relation to the proportion of AS transitions to student DTA, regardless of DTA-level. The upper diagram differentiates between lower and higher levels of AS and DTA. Dashed arrows represent non-significant probabilities (p > .05).

Transitions from teacher AS to student CTA

As can be noticed from table 10, the probabilities for transitions from teacher AS to student CTA weren't significant and therefore these results can't be interpreted reliably. The difference scores for probabilities from lower- and higher-level AS to Sensori-Motor Actions, Representations and Abstractions didn't yield significant results either.

Transitions to DTA and CTA for individual teachers and their classes

Consistent with the significant group results, for seven of the thirteen teachers and classes it was found that the probability for transitions from lower-level teacher AS to lower-level DTA expression (imitation and consequence) was significantly higher than expected based on chance (range p(t) = .61- .78; $p < .01$). For two classes, the probability for transitions from higher-level AS to higher-level DTA was significantly higher than expected based on chance (p(t) = .62 and .67; $p < .01$ and $p < .05$).

For transitions from AS to CTA for individual teachers and their classes a picture emerges of more interindividual differences and less consistent results when distinguishing between lower-level and higher-level AS transitions. This might explain the non-significant group results. At the individual level, for only a few teachers some significant results were found. For transitions to the Representations level of student CTA (overall the most frequented level) two classes showed significantly higher probabilities from lower-level AS (p(t) = .82 and .87; $p < .05$), and three classes significantly lower probabilities (p(t) = .25, .43 and .46; $p < .05$) than expected based on chance. From higher-level AS to Representations two teachers had significantly lower probabilities (p (t) = .20 and .40; $p < .05$). For transitions to Sensori-Motor Actions and Abstractions contrasting results were observed.

What is the temporal relation between teachers' level of AS and students' immediate response in level of DTA and CTA in the domain of lessons with creative tasks? (RQ3b)

Table 11 summarizes the transitional probabilities in lessons within the domain 'Creating music' (n = 10), from here on termed creative lessons. A relevant question with regard to these probabilities is, whether differences exist in student DTA and CTA performance between teacher provision of higher-level AS compared to lower-level AS in creative lessons, and secondly, whether this differs compared to the findings for all lessons.

Comparing table 11 and 10, it can be noticed that in creative lessons the probabilities for AS-self transitions to lower-level AS are somewhat lower (p(t) = .77; p < .05), compared to these probabilities across all lessons (p(t) = .86; p < .01) but still higher than expected based on chance. The probabilities for transitions from both lower-level AS and higher-level AS to higher-level DTA are significantly higher than expected based on chance ($p < .01$). The probability for transitions from higher-level AS to lower-level DTA was lower than expected based on chance ($p < .01$).

For CTA the transitions from lower-level AS to student performance on the Sensori-Motor Actions ($p < .05$ was significantly lower and to the Representations level ($p < .01$) was significantly higher than expected based on chance, but none of the difference scores were significant. However, the extent of the difference scores for transitions from both AS levels to self and to DTA were significantly higher than expected based on chance. These differences will be further interpreted in the discussion of the transition diagrams for creative lessons.

Table 11: Probabilities transition analyses creative lessons

	AS[a]		DTA[b]			CTA[c]		
	LL	HL	Non	LL	HL	SMA	Rep.	Ab.
Level AS								
LL AS	.77*	.23*	.20**	.50	.30**	.21*	.76**	.04
HL AS	.68*	.32*	.22**	.32**	.46**	.20	.71	.08
Difference	.09*	.09*	.02	.17*	.16**	.00	.04	.05

Note. n = 10 lessons. LL = Lower-level. HL = Higher-level.
[a] Transitions to self (AS-AS).
[b] Transitions from teacher AS to student DTA on the non-substantial level, lower-level DTA and higher-level DTA.
c Transitions from teacher AS to student CTA on the Sensory-Motor Actions (SMA), Representations (Rep) and Abstractions level (Ab).
* $p < .05$ ** $p < .01$

The lower part of figure 7 (transitions to DTA) and figure 8 (transitions to CTA) show that from all AS transitions in creative lessons, regardless of level, the majority are AS transitions to self (p(t) DTA = .61; p(t) CTA = .75). For DTA, this is somewhat higher compared to this probability across all lessons (P(t) DTA = .53).

Transitions from teacher AS to student DTA in creative lessons

In figure 7 the highest probability is marked by a bold arrow from higher-level AS to higher-level DTA (p(t) = .46) which is considerably higher than this same probability for all lessons combined (figure 6). In comparison with all lessons, it stands out that in creative lessons probabilities for transitions from both higher-level AS and lower-level AS (p(t) = .30) to higher-level DTA are higher than expected based on chance. Compared to the results across all lessons, it can also be noticed that the probabilities for transitions to non-substantial student expression, top right, are lower in creative lessons for both lower-level AS (p(t) = .20) and higher-level AS (p(t) = .22)

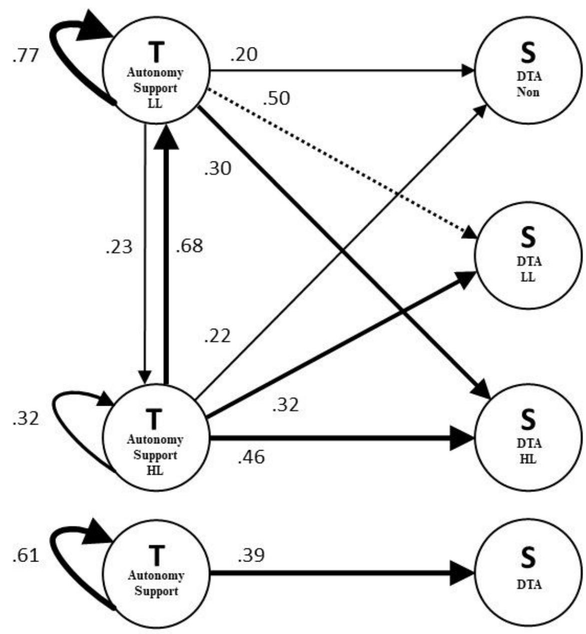

Figure 7: Transition diagram with transitions and probabilities from Teacher Autonomy Support (AS) to Student Divergent Thought & Action (DTA) in creative lessons (n = 10). Note: T = Teacher, S = Student. LL = Lower-level. HL = Higher-level. The lower diagram summarizes the upper diagram in terms of the total proportion of AS-transitions to self, regardless of DTA-level. The upper diagram differentiates between lower and higher levels of AS and DTA. Dashed arrows refer to non-significant probabilities (p > .05).

Transitions from teacher AS to student CTA in creative lessons

For transitions to student CTA, it can be noticed in figure 8 that the highest probability is observed for transitions from lower-level AS to students' achievement on the Representations level (p(t) = .76; *p* < .01) marked by a bold arrow. This means that lower-level AS is likely to lead to students playing relatively simple musical pattern in creative lessons. The probability for transitions from lower-level AS to students' CTA on the Sensori-Motor Actions level, representing students' exploration of sound making, is lower than can be expected based on chance (p(t) = 21; *p* < .05).

Since much less transitions from higher-level AS to CTA were observed, these findings do not provide much insight into differences between lower and higher-level AS for transitions to student CTA in creative music lessons, nor compared to all lessons combined.

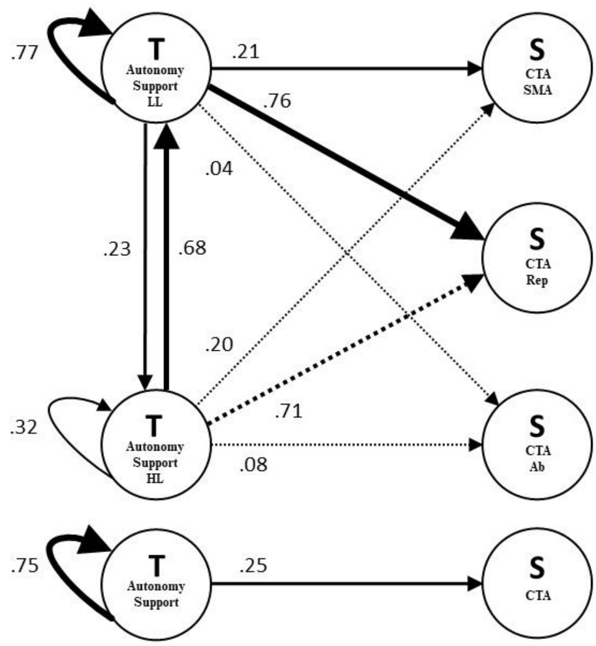

Figure 8: Transition diagram with transitions and probabilities from Teacher Autonomy Support (AS) to Student Convergent Thought & Action (CTA) in creative lessons (n = 10). Note: T = Teacher, S = Student. LL = Lower-level. HL = Higher-level. The lower diagram summarizes the upper diagram in terms of the total proportion of AS-transitions to self, regardless of CTA-level. The upper diagram differentiates between lower and higher levels of AS and CTA. Dashed arrows refer to non-significant probabilities (p > .05).

Exploring lower- and higher-level AS transitions to student DTA and CTA: qualitative analysis

To develop more understanding of the nature of and interplay between lower-/higher-level AS and student DTA and CTA, the interactions in the following two fragments were analyzed qualitatively. The aim is to deepen the insight into the temporal relation between AS and musical creativity for research question 3. Both fragments are drawn from the same lesson in which children used symbols to compose a short rhythm by clapping their hands and stamping their feet. First, this assignment was explored in a whole-class introduction in which individual students were asked to clap and stamp short rhythmical patterns, that were subsequently repeated by the group. In the introduction possible symbols to notate these patterns were gathered with the students. Both fragments apply to individual work time and provide an illustration of how the teacher helped students to create and notate their own rhythms. In the first fragment the teacher predominantly offered lower-level AS and in the second fragment the teacher provided more higher-level AS and the student higher levels of DTA and CTA. The coded levels for (verbal) AS, DTA and CTA appear behind each utterance. Note that for CTA only musical expressions are coded.

Fragment 1: 00:35:28 - 00:36.35

1. T: [observes a student and points at her dry-erase board] *This is your right hand.* (AS: 3)
2. S: *Yes.* [continues drawing on the board] (DTA: 1)
3. T: *Yes, and you added your foot. So, you have rest-and-hand* [hits table once with hand],
4. *foot* [stamps foot on floor], *hand* [hits table with hand], *rest, hand* [hits table],
5. *hand* [hits table]. (AS: 3)
6. T: [takes away the student's marker to make her stop drawing] *Now you try! I'll count.*
7. [points at the symbols on the board] *1.. 2.. 3.. 4.. 5.. 6.. 7.. 8.. 1..* (AS: 2)
8. S: [hits table and stamps feet according to the counting] (DTA: 2, CTA: 5)
9. T: *Right? Just continue like that.* [teacher walks away] (AS: 2)
10. S: [briefly continues drawing, gets up and walks away from her table]

The teacher first offers space for play by observing (1). Soon teacher AS is diminished through intervening and commenting (1, 3). AS further decreases when the teacher starts modeling and explaining (3-5). She maintains offering lower-level AS by instructing the student to play (6), pointing at the symbols and by counting (7). Although the student wrote down a rhythm herself, she imitates the teacher's play (lower-level DTA). In terms of CTA she is exploring (mapping) a new (the teacher's) version of her own rhythm at the representations level. However, it is likely that she isn't able to perform this level by herself. An indication for this is that the student doesn't start practicing after the teacher leaves but starts drawing and walks away (10). This was preceded by a lower-level AS check question and instruction to continue (9).

Fragment 2: 00:36:20 – 00:37:29

1. T: [shoves student's dry-erase board in front of him] *Did you make your own? (AS: 4)*
2. S: *Yes. (DTA: 1)*
3. T: *Okay, can you play it to me…? (AS: 7)*
4. S: [plays his rhythm… stops…plays] (DTA: 5, CTA: 4)
5. T: *This one* [points at symbol] *returns a few times, but I don't think I heard it. (AS: 3)*
6. S: *Yes, I'm doing …* [plays] (DTA: 4, CTA: 5)
7. T: *Yes! Yes!* [smiles and gestures enthusiastically] (AS: 7)
8. *Now your right hand continues* [points at right hand], *first it stopped. So the*
9. *right hand goes 1.2.3.4* [points at symbol and plays along with student] 5.6.7.8
10. *you've got nine even* [points at symbol and hits table with hand] *1.2.3.4* (AS: 3; DTA:4)
11. S: *6.7.8 this one has to go.* [erases symbol from board] (DTA: 4)
12. T: *Right, and then again. Try to count. At one you do that one.* [points at symbol] (AS: 2)
13. S: [practices the now somewhat altered rhythm] (DTA: 4, CTA: 5)
14. T: *And not too fast, take it easy.* [steps back] (AS: 2)
15. S: [plays] *Yes, I did it!* [raises both hands in the air] (DTA: 5, CTA: 6)
16. T: *Well, you created it yourself! (AS: 3)*

In this fragment the teacher non-verbally elicits the student's attention (1) and asks a medium AS check question (1). She offers high AS by inviting the student to play his rhythm (3) and by listening and observing. The student plays his rhythm independently, but hesitantly and irregularly (4) on the Single Representations level of CTA. He reaches the DTA Originality level (4) but only at the end (14) he plays the intended rhythm by himself correctly, on the Systems level for CTA.

When the teacher notices an omission, she makes a medium AS remark (5), but without instructing or modeling. AS is increased by offering the student space to play again (6) which he does correctly. The student now acts on the Mapping level for CTA since he plays a variation of the first rhythm. The teacher encourages the student (7) and then provides medium AS positive feedback by explaining what went right (8). Subsequently AS is diminished by commenting and playing along with the student (8-9). He realizes a mistake and erases a symbol to achieve the intended rhythm (11).

AS fluctuates as the teacher combines giving stimulating feedback with lower-level AS instructions (12 and 14). By stepping back and observing the student play (14, 15), she offers higher-level AS. She wraps up with a medium AS compliment (16).

Throughout the fragment the student mapped various variations (4, 6, 9, 13, 15) of the original rhythm, one of which together with the teacher (9). His playing moved from Single Representations (4) to Mapping (6, 9, 13) and, by playing his own finalized rhythm independently twice, finally to the Systems Representations level (15) for CTA.

In the second fragment, the teacher showed more higher-level AS by asking questions, encouragement and offering space for play, even though the task was the same. Furthermore, the teacher's AS showed more fluctuations, depending on the student behaviour observed. The student showed more self-determined action, and emergence of both student CTA and DTA could be observed. In both fragments the teacher was quite focused on students' CTA in terms of appropriate play, i.e., achieving the system's level of the Representational tier. In addition, it can be noticed that the teacher's embodied actions also influence the level of AS.

Summarizing, the results for RQ 1 and 2 indicate that a) there is still room for improvement of teachers' AS, b) for students' DTA and CTA in musical creativity. The findings for RQ 3 suggest that c) DTA and CTA each have their own relation with AS in terms of students' immediate responses, with DTA significantly more often being preceded by higher-level than lower-level AS, especially in lessons with creative tasks, while the relation between AS and CTA in these lessons yielded ambiguous results.

4. Conclusion & discussion

The present study aimed to examine the extent of teachers' Autonomy Support and students' Divergent and Convergent Thought & Action during primary school music lessons, and explore differences between classes, lessons, domains and grades, in addition to examining the temporal relation between teachers' AS and students' DTA and CTA.

4.1 Overview findings

For RQ 1a about the extent of teacher's Autonomy Support, the findings show that teachers offer predominantly lower-level Autonomy Support (AS) in music lessons. Previous research into teachers' interaction strategies in science lessons at primary schools indicated the same tendency towards instructing and informing (e.g., Van Vondel et al, 2017).

RQ 1b focused on differences between teachers, lessons, domains and grades. Although teacher means were grouped quite close together, some interindividual differences were found. Using micro-level data allowed identifying teacher, lesson, domain and, to a lesser degree grade as differentiating factors for the level of AS offered, suggesting that AS in music lessons is dependent on multiple interacting components. As the association for grade was weak, teacher AS might be less dependent on student age. Rather, it emerges in the complex dynamic system of teachers' interaction with the students and the (musical) task through co-regulation (Kupers, 2017). For domain, creative lessons seemed to offer more affordances for teachers to offer higher-level AS. Possibly in lessons without creative tasks students are expected to carry out pre-set tasks more often, according to the instructions of the method and/or teacher.

RQ 2a pertained to the extent of musical creativity in terms of students' Divergent and Convergent Though & Action. For DTA the largest proportion of student expression concerned lower-level DTA such as imitation and playing on the consequence level, according to the teachers' instructions or the digital board. These findings echoed previous research into the emergence of children's novelty in individual musical composition tasks (Kupers & Van Dijk, 2020). In line with this study, the distribution of the data in the present study was quite skewed to the right for DTA, indicating that performance on the highest levels was quite rare. For student CTA the same tendency existed with student expression in the single and mapping Representations levels, outweighing the systems level. This is in line with earlier research into talented performance (Den Hartigh et al., 2016). Perhaps higher-level performance requires the existence of a foundation of lower-level thought & action. A key question for development is which proportion of higher-level performance is needed to trigger and maintain a positive learning spiral. The present findings therefore might be interpreted as the existence of some unused potential. For CTA students were found to be mostly active in the Representations tier, working on assignments focusing on exploration of relatively simple rhythmical patterns. Previous (interventional) research into children's scientific reasoning, using the same scale yielded similar results, with primary students in teaching-as-usual conditions rarely achieving even this tier (Van Vondel et al., 2017).

Regarding RQ 2b about differences between teachers, lessons, domains and grades, for DTA some differences were found between classes/teachers. Using micro-level data, stronger differences were found for especially lessons and musical domain. An explanation might be that the DTA-levels achieved were quite dependent on the nature of musical activity, hence on the tasks. This aligns with CDS and 4E theory in the sense that emergence of creativity is embedded in the environment and relies on its affordances, both in the social and material sense (Glaveanu, 2013). It is possible that some domains, for instance creating music, the assignments offered higher affordances for higher-level DTA. For grade a difference between lower and higher grades existed, with students in grades 3 and 4 showing more imitation, whilst grade 5 and 6 students engaged more in consequence play, such as play-alongs on the digital board.

For RQ 2b for CTA some differences between classes/teachers were found. In line with results for DTA, CTA differed between lessons, sometimes also by the same teacher. Almost half of the classes occasionally achieved the Abstractions tier, mapping variations of more complex musical phrases. This was sometimes observed even for grade 3 students. Given the moderate association for grade, possibly, under the right circumstances, also young children can achieve the

Abstractions level. The nature of the musical task seemed to be a differentiating factor too. In singing, achieving the Abstractions tier is easier, compared to in improvisation. A possible explanation is that singing lessons are more frequent so that children have more experience in singing, and that often the teacher sings along. Within the Representations tier, domain appeared to be a differentiating factor. It appeared that there is a lot to explore in this zone, and that students were able to achieve this tier more frequently in creative tasks, with or eventually without teacher support. The high proportions for exploring variations of rhythmical pattern in the Representations tier, and to a lesser degree in the Abstractions tier, underline the importance of mapping. This is in line with previous research into children's composing by Burnard & Younker (2004) who emphasized the importance of differentiating creative tasks in school music education.

Overall the findings for RQ2 support the idea that CTA and DTA in musical creativity are two sides of the same medal (Runco & Acar, 2012). The fluctuations found within classes for both CTA and DTA, underline that alternating between the two, according to the demands of the particular phase in the creative process (Cropley, 2006) is important. DTA can't do without CTA and novel musical actions become meaningful when they contain appropriateness too.

The interindividual and intraindividual differences between teachers and their classes, and the differentiating influence of lessons and domain, exemplify the interactional dynamics in the talent triangle of students, teacher and task as a complex system. There is mutual influence, but we don't know exactly which component causes what. There are no indications for isolated causality of components, rather for cyclical causality. How musical creativity is enacted and globally emerges within the interaction of these components doesn't depend on component-dominant dynamics but on interaction-dominant dynamics (Van Orden, 2003).

For RQ 3a about the temporal relation between autonomy support and students' immediate response in terms of musical creativity the transitions from AS to DTA and CTA were examined, and further explored by thematic analysis of two contrasting fragments. It was found that both lower- and higher-level AS were more often followed by lower-level DTA. However, when students showed higher-level DTA, this was more frequently preceded by higher-level AS. In previous research into the association between teacher behaviour and students' novelty in music composing (Kupers & Van Dijk, 2020) a similar pattern was found. In the present study high proportions of imitation were found, implying that young children are drawn to sounds from their environment and might have a strong liking for imitating sounds which are new to them, and strike or amuse them. An explanation might be that eliciting variation and originality isn't so straightforward and might require persistent higher-level teacher AS in the form of explicit open and inviting follow-up questioning. Overall, for CTA no clear temporal relation was found for transitions from teacher AS to student CTA.

Regarding RQ 3b about transitions from AS to student DTA and CTA in lessons with creative tasks, higher-level AS more often led to higher-level DTA. A possible explanation is that in creative lessons the interaction between teacher, students and task is more explicitly targeted at student performance of variation and originality than lessons in other domains. The thematic analyses of two episodes from a lesson with a creative task, showed that modeling and instructing led to imitation and that offering higher-level AS elicited variation and originality. Concerning transitions to student CTA, the sequential analyses of data of creative lessons yielded ambiguous results. At group level, a positive relation existed between lower-level teacher AS and student CTA for the single and mapping Representations level. But for individual teachers both positive and negative relations were found. Therefore, the question remains: to which extent do students need to be offered a high degree of 'friendly challenge', i.e., AS, in order to develop CTA? The thematic analyses however suggested that the occurrence of higher-level AS led to more autonomous exploration, and that teacher AS fluctuated depending on the student's needs, eventually resulting in achieving the Representational system's level. Additionally, the thematic analyses suggested that the embodied aspects of autonomy support, like offering space for student play by stepping back and observing or by restraining autonomy support through modeling and intervening also seemed to affect students' actions. Since the quantitative findings showed that students, overall, didn't reach the system's level for Representations often, let alone the Abstractions level, and teachers seemed to deal quite differently with offering AS in creative tasks, room for further development seems to exist, for both students and teachers. The mixed results for AS-CTA transitions could be related to a lack of knowledge about offering AS in music lessons and to teachers' insecurity in teaching music reported in research (e.g., Garrett, 2019).

Summarizing, both the sequential and thematic analyses showed that higher levels of musical creativity, especially in creative lessons, were often preceded by higher-level AS although the association with CTA could not be underpinned by the transitional analyses. Obviously, teacher AS can't be high continuously throughout lessons. Rather it can be expected to fluctuate as shown in the sequential analyses of AS-CTA transitions. The findings suggest that adequately timed higher-level autonomy support, and flexibility in offering varying levels of contingent AS, such as in scaffolding, may be required to elicit musical creativity and that this invites students to (re)think and (re)initiate actions in new ways, generating recursive cycles of action and perception. In previous research (Burnard & Younker, 2004) recursiveness in students' creative thinking during composition positively influenced student achievement. Possibly such recursive behaviour draws the system into ever new states thereby changing students' potentials for achieving higher creativity levels.

The degree to which task affordances in creative lessons invite (creative) behaviour depends on students' needs, action capabilities, their personal experience and culture in general (Withagen et al., 2012), making learning highly idiosyncratic. But this goes for teachers just as well. They can choose tasks which afford creativity, but how they interact with those tasks, in terms of autonomy support, is also crucial and depends on their own personal experience, skills and habits. Task demands throughout lessons, communicated by the teacher, change the flow of students' activity (as well as the teacher's own later responses to this), and adjusting to new task requirements intrinsically enhances diversity in behaviour, i.e., mapping, and complexity (Van Orden, 2003). This way the system as a whole, within the interaction of its nested parts, self-initiates variability, eventually affording development.

4.2 Strengths and limitations

The present study is done in a Western primary school context and its results can't be generalized to educational settings in other societies without thoughtful reflection on cultural differences and similarities, as well as differences in conceptions of (musical) creativity.

Although most creativity scholars define (musical) creativity in teaching and learning processes as a dynamic, embodied, material and socially situated phenomenon, in empirical educational research into creativity, studies integrating this view in their design are still scarce. In the present study creativity was studied within a process-based CDS-enactive framework. The aim was to contribute to growth of insight into the conditions and pedagogies best affording development of (musical) creativity in primary schools, by examining temporal sequences in real-time teacher-student interactions.

The study was carried out in a natural classroom context. Studying creativity in real creative processes in regular primary (music) lessons contributes to ecological validity (Kupers & Van Dijk, 2020) but is also time-consuming and complex, because of the many simultaneously interacting influences within such settings. The question is if the relatively small number of teachers and students can be considered a limitation. To what extent do these thirteen teachers qualitatively represent their peers? The notion of generalizability transcends a standard quantitative approach involving large samples. Qualitative generalizability implies that understanding developmental processes and mechanisms requires studying them at the level where they operate, i.e., at the individual level (Steenbeek & Van Geert, 2013). This approach has allowed us to gather a vast amount of rich data of multiple teachers in a naturalistic context, providing the basis for in-depth analysis of concrete temporal sequences in what can be considered representative teacher-student interaction in music lessons.

The term creative thinking in music (Webster, 1990, 2002) has been extended in this study to creative thought & action in music, involving divergent and convergent thought & action. Agency is an important aspect in creative processes and current views on cognitive processes stress the embodied nature of thought (e.g., Noë, 2013) and creative (musical) thought (e.g., Glaveanu, 2013; Leman et al, 2018). These variations of Webster's original terms were used in this study to reflect this agentic and embodied view on creative thought. Although operationalization of musical creativity following Webster's definitions of divergent and convergent thinking in music isn't new, to our knowledge, it is the first time that convergent thought and action in primary music lessons was investigated using a scale based on Dynamic Skill Theory (Fischer & Bidell, 2006). In the present study this scale afforded meaningfully measuring and interpreting dynamics and development in children's rhythmical play in music lessons.

The present study didn't follow a classical correlational approach. Instead, sequential analysis was applied to examine the *temporal* relation between teacher AS and students' musical creativity. In terms of practical value for teaching, this approach has the potential to statistically identify the effects on musical creativity in the unfolding interaction in the classroom. The analyses focused only on transitions from teacher to student and, for the purpose of this study, not the other way around. This approach has provided indications that the association between teacher AS and students' CTA and DTA music lessons is possibly not the same for both modes. Transitions in creative lessons have been examined separately, providing new insights into the task affordances and the interaction with creative tasks by teachers and students.

A limitation of sequential analysis is that only the probabilities for immediate transitions are calculated. Therefore, possible delayed effects of lower- or higher-level AS on DTA or CTA aren't captured. Using mixed-method approaches to analyze interaction, integrating qualitative and qualitative analysis, can offer more insight into patterns of emerging creativity (Kupers & Van Dijk, 2020). Therefore, in the current study thematic analysis was applied to complement the findings of the sequential analyses.

4.3 Implications and future research

In line with the empirical literature (e.g., De Vries, 2015) quite some teachers reported feeling insecure about teaching music before entering this study. Focusing on a perceived lack of musical knowledge and didactics can be severely hindering. Instead of believing that they should be capable of solving every problem students encounter in music lessons, an alternative and more autonomy-supportive attitude is to delve into such problems together with students. This echoes Bandura's self-efficacy theory (1993) which states that being confronted with new situations on the job, helps accumulating mastery experience.

Intervention research involving coaching for teachers can offer more insight into the extent to which offering autonomy support in music lessons is trainable and what effect this has on students' musical creativity. Interventions aimed at autonomy support, student motivation and engagement, have yielded positive results in other domains (Reeve, 1998; Reeve et al, 2004; Su & Reeve, 2011; Reeve & Cheon, 2014; Van Vondel et al., 2016; Cheon et al, 2020) and could also be useful for primary school music education. The present study provided indications that an appropriate balance between offering lower- and higher-level AS might be needed in music lessons. Especially when students encounter problems, contingent (autonomy) support such as in scaffolding might be required (Steenbeek et al, 2012). A recommendation therefore is to integrate scaffolding as a teaching strategy in music education, into such an intervention study.

Future research could focus on the temporal bi-directional relation between Teachers' AS and students' musical creativity in the natural classroom context of primary school music lessons, for instance by using CDS techniques such as t-pattern analysis (Magnusson, 2000), which affords investigating delayed responses in the data that do not necessarily occur immediately after stimulation. Other possibilities are recurrence quantification analysis (Webber & Zbilut, 2005) or State Space Grid Analysis (Lewis et al, 1999; Hollenstein, 2012) to study patterns in interpersonal coordination.

For validity reasons, i.e., to enhance the comparability between lessons and develop a better understanding of the relation between autonomy support and musical creativity, future research should focus on lessons containing creative tasks instead of lessons in varying musical domains.

In the present study the focus was on verbal AS, but a large part of teacher-student interaction in music lessons is non-verbal and musical. Teachers' and students' gesturing for instance, has the power to both reflect a learner's understanding, but also to mediate change in that understanding (Novack & Goldin-Meadow, 2015). In music learning teachers' musical behaviour, including modeled play and gesturing is particularly important (Simones, 2017). Moreover, musical creativity may be expected to develop within the coupling of verbal, non-verbal and musical aspects of classroom interaction. Therefore, future research must integrate verbal, non-verbal and musical aspects of offering autonomy support to help generalist teachers to deal with, and enjoy the multilayered reality of primary music education.

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