

The Mathematics Enthusiast

Volume 15
Number 1 *Numbers 1 & 2*

Article 12

1-2018

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Recommended Citation

Kremling, Julia; Arndt, Nadine; Roman, Anja; Zilm, Melanie; and Straehler-Pohl, Hauke (2018) "Dancing on the junction of mathematics and bodily experience," *The Mathematics Enthusiast*: Vol. 15 : No. 1 , Article 12.

Available at: <https://scholarworks.umt.edu/tme/vol15/iss1/12>

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Dancing on the junction of mathematics and bodily experience

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ABSTRACT: In this experimental paper, we document an experience of artistic research, initiated by searching an answer for the question "Is it possible to learn mathematics through dance?". We reflect on three different pathways towards experiencing mathematics in dance: theory, methodology and artistic experience. Following these pathways requires us to challenge established assumptions about mathematics and research and finally allows for exploring the dancing body itself as the potential space of mathematical knowledge. While we remain far from our initial aim of being able to make concrete suggestions about how to integrate dance as an integral part of school mathematics, this article reveals the emancipatory potential of dancing mathematics, facilitating positive experiences with mathematics that hitherto appeared impossible to us.

Keywords: Dance, body, mathematics, artistic research, experience, aesthetic education

Introduction

It all began with a simple question: "Is it possible to learn mathematics through dance?". Soon it appeared to us – four female prospective primary school mathematics teachers who chose this question as the starting point for their research project in a teacher training seminar² – that we would need to engage in some more foundational questions in

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² Throughout the text, "authors" stands for Nadine Arndt, Julia Kremling, Anja Roman, Melanie Zilm, as it is their research experience that is documented in this article. Hauke Straehler-Pohl has lead the course from which this research emerged and supervised the research process. He is listed as a co-author, as he

the first place before we could make this question meaningful for us and others in a way we desired.

We realized how the subordination of the body under the mind, the Cartesian dualism, was already intrinsically inscribed into our question: it posits dance as a bodily means that should serve the cognitive ends of learning mathematics. We did not want to resign ourselves to understanding dance as a mere tool and the body as a means to help students better meet the requirements imposed on them by school mathematics. We wanted to explore the dancing body itself as the space of mathematical knowledge. Soon we noticed that in order to maintain this self-imposed entitlement, we would need to be more radical and release school mathematics itself from institutional utilitarianism. But how is this possible?

Searching for methodologies with the potential to investigate this apparent impossibility, we found ourselves confronting a similar problem concerning research methodology: Is the Cartesian dualism not already inscribed into all the conventional research methods that were available to us? This question led us to search for and develop a notion of research that was uncharted territory for us: a notion of research that is oriented towards exploring the inexpressible instead of expressing the explored, towards knowing as a dynamic process instead of knowledge as a static product, and towards sharing research experiences instead of disseminating research results. Artistic research methodologies (Brandstätter 2007, 2013; Goroncy & Patracaro-Goertscher 2015; Kämpf-Jansen 2012; Peters 2013; Roesner 2015; Sutherland & Acord 2010; Toro-Pérez 2010; Vollmer 2015) implement such notions of research.

And finally we reached the insight that our enterprise would require us to challenge the very notion of mathematics itself. Instead of searching for an alternative way to better understand the apparently most rigorously and clearly defined form of knowledge called mathematics, we ended up going a long path redefining what we had hitherto taken for the truth of mathematics and the truth about mathematics.

The article is structured in three sections. Each of these sections stands for a different pathway towards connecting dance and mathematics: (A) theory, (B) methodology and (C) artistic experience. While the three routes necessarily appear in a linear structure in a journal article, one after the other, the sequence of reading is not of necessity. Readers are invited to read these sections in whatever sequence they like. The canonical sequence A-B-C might on the one hand cause irritation: "Why going so deeply through all this rationalistic fuzz about theory and methodology, when the authors' self-entitlement is exactly to liberate the body and experience from the superiority of rationality?" On the other hand, during our own research process, it was exactly going through the corpora of rationalistic theoretical knowledge in the first place that allowed us to devote ourselves all the more to the building of experiential knowledge later on. We could *emancipate from rationality through rationality* one could say. Thus, if the reader should decide to start with the route of artistic experience (C) in order to comprehend the theoretical considerations of route A in relation to the "experiences" made while "travelling" on route C, we strongly encourage her to "close" the reading with revisiting route C nevertheless (e.g. C-B-A-C).

Along pathway A (theory), we will unfold a conceptual framework for aesthetic education (Bildung) and a notion of mathematics that is commensurable with this framework.

Along pathway B (methodology), we will unfold our experimental experience-oriented research methodology and legitimize all the methodological decisions made in relation to the (dynamic) research aims discussed in the introduction. Departing from the resources chosen³, we will develop *artistic research* as our methodology of choice for facilitating *the experience of mathematics in dance*.

Along pathway C (artistic experience), we unfold our bodily encounter with dancing mathematics: We present fragments of the reflection protocols which we have produced following three significant moments of research experience, and re-arrange

³ The selection of resources was appropriated by the intellectual desires and pragmatic necessities emerging from the research process itself and not by the standards of the international scientific community of mathematics education. The reader will quickly notice that these resources draw mainly from German speaking literature and seldom draw from mathematics education.

them as a sort of dialogue. We then present two pieces of art, namely a video piece in which we re-perform our journey towards the experience of mathematics in dance and a poem that condenses the reflections of these experiences (of one of us) in an artistic form. These three parts are meant to complement and simultaneously cause frictions among each other, opening a space of possibility in-between the word and the unspeakable.

Finally, we give a short outlook on where our journey may take us in the future.

Route A: Our theoretical pathway to experiencing mathematics in dance - Aesthetic education (*Bildung*) and mathematics

Approaching the question "Is it possible to learn mathematics through dance?" required us to develop a notion of "learning" that could adequately address its experiential and aesthetic dimension, as well as developing a notion of mathematics that is on the one hand sufficiently commensurable with our chosen notion of learning and on the other hand sufficiently connectable to the scientific community of mathematics (education). We did not want to weaken the definition of mathematics into something that would neither be useful nor meaningful anymore.

Aesthetic education (Bildung)...

With *Bildung* we focus on a particular form, particular moments of education that entail the transformation of the relation in which the subject being educated (*sich bildend*) finds itself with the world. *Bildung* thus entails a transformation of subjectivity, in which the subject reaches beyond itself, in which it becomes, in a sense, more or (an) other than it was before.⁴ At the heart of *aesthetic Bildung* (see e.g. Schiller 2002/1795) is then a certain notion of aesthetic recognition that focuses on the potential of transformation inherent in aesthetic experience.

In the German speaking tradition, aesthetic recognition is often captured by the notion of "*leibliches Lernen*" (learning through the lived body⁵). In a first moment, it entails (sensual) perception, invention, exploration of the new and in a second moment it

⁴ See e.g. Biesta (2002) for a contemporary and internationally connectable discussion of the concept of *Bildung*.

⁵ see the next section for a clarification of the term "lived body" (*Leib*).

entails the incorporation (*Einverleibung*) in practice (Aissen-Crewett 2000, p. 12f.). The first and second moment, referred to here, are not meant to be taken chronologically but rather take place simultaneously and stand in a reflexive relationship to one another.

While the fine arts have elaborated ways to work deliberately with aesthetic recognition, it is not limited to processes within artistic practice. Aesthetic recognition can also occur in scientific practice, even though it often occurs rather implicitly and unnoticed in this context. At times, adherence to aesthetic criteria even affects the likelihood of knowledge being accepted by the scientific community. This applies in particular to the discipline of mathematics, where sudden inspiration is an indispensable resource, which is closely related to aesthetic characteristics (Aissen-Crewett 2000, p. 12f.). Aesthetic recognition emerges from aesthetic experience.

One crucial characteristic of aesthetic experience is that it is self-sufficient. It is necessarily bound to emotions and affects. In order for aesthetic experience to facilitate moments of aesthetic *Bildung*, however, completely succumbing to emotions is insufficient. Conscience and thought are essential in order to grasp and experience an object aesthetically and to relate it to former or alternative experiences. Aesthetic experiences are therefor constituted by an entanglement, a reflexive interplay of emotion and cognition. They urge the individual to open up for something (*ein Sich-Öffnen gegenüber dem Gegenstand*) and to pay attention to phenomena outside the individual. Aesthetic experiences take up bodily and mundane relations, sensitize for differences and classifications and increase the power of imagination (Aissen-Crewett 2000, Brandstätter 2013). Despite dominant perceptions of science as an emotionless discipline and as the realm of pure rationality, the reflexive entanglement of emotion and cognition is not restricted to the arts and public life:

The boundaries between art and non-art have long become fluid, a sharp border cannot be drawn anymore. Art has become reflexive, in the same manner that science has become aesthetic [...]. The purpose of the arts is not the embellishment of the world, but its recognition" (Brandstätter 2013, p. 14, translation HSP).

Following this line of thought, we assume that dance, as a form of the arts with a bodily (*leibsinlich*) access to aesthetic experience has the possibility to facilitate aesthetic recognition of mathematics.

... and a commensurable notion of Mathematics

While it initially seemed perfectly clear to us that there is an unambiguous definition of mathematics, our first attempts to find a common denominator for such definition quickly led us to the insight that none of us could actually come up with a more or less clear-cut answer to the question "What is mathematics?" Even though mathematics remains a shelter of secure truth in the public discourse, represented by unambiguous numbers, symbols and functions, we could not find a definite and precise definition of mathematics in the literature. Even wikipedia⁶ describes mathematics as a human practice and points out that there "is a range of views among mathematicians and philosophers as to the exact scope and definition of mathematics".

According to Lakoff and Nunez (2000, p. xv), such discrepancy is based on a myth they call the "romance of mathematics", which we summarize in the cultural theses that 1) mathematics is abstract and disembodied, 2) mathematics exists objectively beyond and independent of human existence and experience, 3) its truth is universal and thus provides rational structure even to the physical universe, 4) mathematics is the language of nature, and 5) that reason itself must follow the disembodied laws of mathematics.

Relating these cultural theses to our everyday experiences, we can see one reason for maintaining these theses is that they provide people a sense of comfort: Mathematics is there for me, without me necessarily contributing anything to it – I do not need to understand mathematics for it to make sense. On the other hand these cultural theses frequently put mathematics in a non-reachable space and leave people with a negative mathematical self-perception and a feeling of helplessness towards mathematics.⁷

Nunez and Lakoff (2000) oppose this romantic view of mathematics with an alternative notion of mathematics. They insist that the human mind and human thinking are not only intimately bound to the human body but that they are constitutively

⁶ Retrieved from <https://en.wikipedia.org/wiki/Mathematics> on December 19th, 2016.

⁷ See Lundin & Storck-Christensen (2017) and Straehler-Pohl (2017) for analyses of how the ambiguous affective positioning of people towards mathematics is effective in bonding them even more effectively to it.

dependent on the body. A transcendental mathematics that exists independently of the human thus cannot exist for the human. The human brain can only develop abstract ideas within the material realm on which the human mind depends. Nunez and Lakoff (p. 5) propose three theses, on which they ground an alternative and bodily bound notion of mathematics:

1. *The embodiment of the mind.* The detailed nature of our bodies, our brains, and our everyday functioning in the world structures human concepts and human reason. This includes mathematical concepts and mathematical reason.
2. *The cognitive unconscious.* Most thought is unconscious—not repressed in the Freudian sense but simply inaccessible to direct conscious introspection. We cannot look directly at our conceptual systems and at low-level thought processes. This includes most mathematical thought.
3. *Metaphorical thought.* For the most part, human beings conceptualize abstract concepts in concrete terms, using ideas and modes of reasoning grounded in the sensory-motor system. The mechanism by which the abstract is comprehended in terms of the concrete is called conceptual metaphor. Mathematical thought also makes use of conceptual metaphor, as when we conceptualize numbers as points of a line (Nunez and Lakoff, 2000, p. 5).

The human mind thus simply cannot conceptualize absolutely abstract entities, but necessarily remains flexible in the materially bound cognitive work of abstraction: "Is a zero a point in a line? Or is it the empty set? Or is it just a number and neither point or a set? There is no answer" (p. 6). Nunez and Lakoff's notion of mathematics, that inscribes ambiguity into the very heart of mathematics, thus ensures the connectivity between mathematics, aesthetic experience and dance, without which our search for a mathematical experience in dance would turn out to be without foundation. It provides our conceptions, perceptions and imaginations of mathematics a space wide enough to sound out mathematical experiences and recognition in bodily expression. It is within the aesthetic space opened by dance, in which we seek to gain and transform our awareness about and towards mathematics. It is this space that we hope to better understand, both bodily and rationally, the entanglement of the dancing body and the mathematical mind.

Route B: Methodological Pathways to experiencing mathematics in dance - The body and artistic research

The body turn in the social sciences

This article emerges from the aim of exploring whether and how it might be possible to experience mathematics in dance. But how can bodily experiences and bodily recognitions be adequately addressed under methodological control? Which instruments do the sciences offer in order to gain and represent pre- and non-verbal knowledge? The latter question represents an unsolvable dilemma that is currently discussed in sociology and that has resulted in the establishment of a new field of sociology, the sociology of the body. Since the 90s, the discipline of sociology has witnessed a "body turn" (Gugutzer 2006), or "corporeal turn" (Shilling 2003)⁸, which seeks to address the role of the body for the constitution of the social. This body turn is based on the assumption that any human (inter)action is always also bodily action and thus cannot be ignored by sociology. The sociology of the body thus claims that the body should not only be made an object of research, but furthermore must be integrated in the building of theories as well as in the epistemologies of sociology.

Initially, we were inspired by Pierre Bourdieu's (1982) concept of the habitus, according to which the body is a memory, a storage of social structures with body and society standing in a reflexive relation. For Bourdieu, however, the body is more than a material storage medium for rationality. He admits a certain space for bodily recognition (Bourdieu 1992, 2001). However, the concept of habitus turned out as not far-reaching enough, as it tells little about *how* a habitus is acquired and even less about the role of bodily experience in this acquisition (Gugutzer 2006). As we were initially interested in the question of whether it is possible to *learn* mathematics through dance, a framework that could address this bodily mode of acquisition appeared essential to us.

⁸ While the term "body turn" is commonly used in German-speaking sociology, "corporeal turn" is much more widespread in English-speaking sociology. As the position that we develop through this section is embedded in the German-speaking discourse on the body, we will subsequently use the term "body turn". Gugutzer (2006) explicitly contrasts "Angloamerican positions" (p. 22ff.) to "French and German positions" (p. 25 ff.).

Theories of the "lived body" that have their roots in phenomenology (e.g. Merleau-Ponty 2003, Schmitz 2003, Plessner 1975) have therefor been discussed as an indispensable complement for integrating the body as an epistemological foundation of sociology. These theories attribute the body its own potential of self-perception, self-experience that eludes rational control (Gugutzer 2006, p. 16). These theories first distinguish two dimensions of the body: the "body" (*Körper*) that *we refer to*, that we have, that we talk about, that we shape on the one side and the "lived body" (*Leib*) as an instance in itself that *takes reference*. Our lived bodies know something, that might not yet be explicitly accessible for us; our lived bodies communicate something, while we might not yet be even aware of the message and/or the articulation; our lived bodies shape themselves and occasionally elude our attempts to instrumentally bring them into shape (Straehler-Pohl, Bohlmann & Ferrin, forthcoming). Body and lived body, however stand in a reflexive relation, permeate and influence each other. Understanding the body as an entanglement of *body (Körper)* and *lived body (Leib)*, we can start conceptualizing this entangled body as a subject of its own: bodily perception is an entanglement of a subject-position with an object-position. The body is simultaneously perceiving and perceivable, seeing (*sehend*) and visible (*sichtbar*), feeling (*fühlend*) and tangible (*fühlbar*)⁹. Accordingly, the body bears a potential to become a subject doing research instead of being condemned to being an object, upon which research is being enacted. According to Abraham (2002, p. 194, translation HSP), the greatest potential of recognition that

a human can possess, [...] is the capacity, to bring the bodily [(*leiblich*)], sensual and cognitive experiences into play and use them as sources of knowledge and recognition. [...] The lived body [(*Leib*)] is a storage of experiences and knowledge of an exceptional kind and can therefor lead to alternative knowledge.

However, research tools that have the potential to integrate rational with experiential sources of recognition in a methodologically controlled way remain a

⁹ We have added the German words, that we would use when talking in our mother language in order to show how the attributes that describe the active and the passive dimension are already inseparably linked to each other for us by their etymological origin: *sehend* and *sichtbar* stem from the verb *sehen* (to see), *fühlend* and *fühlbar* stem from the verb *fühlen* (to feel).

desideratum, a gap, in the social sciences (Gugutzer 2015, p. 144). The development of a methodology for experiencing mathematics in dance addresses this gap and seeks to submit to discussion such a research tool.

Artistic research

Artistic research aims at making negotiable and visible the non-rational both in the research-process as well as in its product(s). It has an intrinsically transdisciplinary character that permanently seeks to establish references to the fine arts, the sciences and public practices similarly (Peters 2013, p. 8). As it originated from the fine arts and not from the sciences, it cannot be considered a sub-discipline of the sciences, but marks a category of research of its very own (Brandstätter 2013, p. 65). It focuses particularly on non-artistic problems (e.g. problems that are usually subjects of sociological, educational, etc. research) and investigates them through aesthetic-artistic acts (Kämpf-Jansen 2012). In particular, it addresses those boundaries of public and scientific discourses that make cultural theses visible and negotiable, like subject-object-relations, gender-relations or forms of labor (Vollmer 2015, p. 53f.). The widespread cultural thesis that mathematics is a strictly abstract, bodyless/disembodied discipline appears as an excellent example of such a discursive boundary. It makes our aim to challenge such cultural thesis through exploring the possibility to experience mathematics through dance a perfect problem for artistic research.

Artistic research deliberately makes use of the intersections of art and science and positions itself as a transdisciplinary process that initiates collaborative forms and formats by establishing "relations and interactions between different forms of knowing that have formerly been unconnected in the system of science" (Peters 2013, p. 8, translation HSP). An inherent aim of artistic research is thus to deliberately transgress the boundaries of established disciplines and to challenge them. It aims at challenging established scientific positions and methods themselves (Vollmer 2015, p. 53f.).

Recognition and knowledge (Erkenntnis) as an experiential process in artistic research

By its transdisciplinary and aesthetic approach, artistic research does not only set out to bring different forms of knowledge into interaction, but also to create new epistemic spaces (Peters 2013, p. 8). While proclaiming an own and particular notion of recognition and knowledge that builds on aesthetic experience (Brandstätter 2012), artistic research nevertheless seeks the analytic confrontation with scientific and mundane notions of recognition and knowledge. The pivot of knowledge-building, however remains aesthetic experience: it structures and constitutes the process of artistic research, emphasizing bodily and sensual experience (*leibsinliche Erfahrung*), the non-rational, the tangible (*das Erfahrbare*) and a radically processual character (Vollmer 2015, p. 63).

Artistic research aims at making the non-rational knowledge that (can) emerge(s) from the arts bodily and sensually tangible for an audience (in analogy to a readership in the sciences).

While scientific research is oriented towards [cognitive] recognition, the arts are oriented towards experience. Even though artistic action can certainly lead to recognition and the production of new knowledge, its main concern is not [cognitive] recognition, but the initiation of the possibility of experience (Toro-Pérez 2010, p. 38, translation HSP).

Another difference to the sciences is the form of knowledge that is produced by the arts (and artistic research). While the sciences tend to reify analytically produced knowledge as *fixed, secured and certain products*, the experiential knowledge produced by the arts is to be found in *processes*, that remain *finally insecure and productively uncertain* (Vollmer 2015, p. 62). This processual notion of knowledge makes the practice of artistic research an active and dynamic event in which knowledge itself becomes a practice (Roesner 2015, p. 28). Artistic research thus does not aim at a linear structure that constructs knowledge in form of a staircase, on which each secure recognition reified in knowledge builds a new step. The knowledge emerging from artistic research rather resembles a dollhouse, in which all the installed pieces of knowledge can be re-assembled like furniture over and over again, always bearing the possibility to completely tidy out before a presentation. Sutherland and Acord (2007) therefore contrast the "experiential knowing" of artistic research to the "situated knowledge" of the sciences.

The concept of recognition and knowledge of artistic research can thus be described as an experiential process, in which the noun "knowledge" is challenged by the

verb "knowing" (Roesner 2015), deliberately playing with different notions of recognition. Artistic research thus endorses an ambiguous, insolubly contradictory form of recognition, which is "both rational and pre-rational, both subjective and general" (Kämpf-Jansen 2012, p. 22, translation HSP).

The presentation as an essential part of the artistic research process

As artistic research conceives recognition and knowledge as parts of a permanent process, the dissemination of research necessarily has to take a different role. As scientific research strictly distinguishes between the process and the product of research, products are disseminated (even though these products may reflect the research process as their object of study). In artistic research, the presentation is in contrast understood as an intrinsic part of the research process, exerting a non-deniable (and at times crucial) impact on the research process itself.

The process is performative, that is, it is subject to continuous formation and re-formation, so that the whole fabric remains in motion and is subjugated to persistently new decisions until the very end" (Kämpf-Jansen 2012, p. 19, translation HSP).

For this reason, artistic research is often presented on stages, conceding the performance of the presentation an experimental character, giving it the selective aim of feeding back into the knowing that has been gained hitherto. The presentation thus becomes a crucial part of the research process (Peters 2013, p. 9f.). While the processual nature of the presentation appears as a coherent consequence of the epistemology, which artistic research builds upon, it leads to a range of difficulties concerning the dissemination of the "research findings" to an audience. While the form of presentation can establish a certain transparency and comprehension of the process of formation of artistic research, it remains finally uncertain and ambiguous, whether artistic research succeeds to 'make itself understood' and whether it can have the desired impact on scientific discourses (Roesner 2015, p. 30). In artistic research, the presentation is thus coupled with a commentary that reverses the processual and performative emphasis of the presentation and juxtaposes it with a complementary emphasis on rational recognition. This dual form of presenting research (presentation + commentary) can be conceived of

as doing the (impossible) split between rational and irrational knowledge, making the "knowing" visible inside this split.

Reflection of subjectivity in artistic research

Artistic research is finally always a subjective form of research, as it inevitably builds on a subjective concept of experience. The researchers engage bodily (*leibsinlich*) with their research questions. Through making aesthetic experiences, researchers become the object of research themselves. Artistic research thus subverts the distinction between researcher and researched (Roesner 2015, p. 29). This leads to a strong emphasis on (subjective and emotional) self-reflection and introspection. Such reflection can take both scientific as well as artistic forms, e.g. diaries, sketches, diagrams, collages, poems or play. Such reflections always aim at sounding out access to one's own subjective approaches and positioning (Kämpf-Jansen 2012, p. 21f.). Our research aim to find a pathway to experiencing mathematics in dance makes us full-fledged objects of study ourselves.

The particular potential of dance as an instrument of artistic research

According to Brandstätter (2007, p. 41, translation HSP), dance can be defined as a "knowledge-culture of sensual-dynamic knowledge". The notion of recognition and knowledge, which Brandstätter develops for dance ties seamlessly to that of artistic research as described above, as it does not only share a focus on the dynamic processual nature of knowledge, but also a focus on bodily experience. In dance, the decisive means for such experience is the lived body (*Leib*) and its performatively and sensually driven actions. Dance is a form of communication characterized by the interlocutors' confidence to happen without the involvement of spoken language (Gorony & Petraccaro-Goertscher 2007, p. 181 f.). It is the prototype of nonverbal encounter (Schmitt 2015, p. 123). Building intersubjectivity without talk, dance appears as a sound approach to bring each one of our subjective experiences into communication, without losing their nonverbal dimensions in the mode of verbalization (Schmitt 2015). It furthermore bears the potential to irritate and challenge cultural theses that are already inscribed into the

structure of language. Dance has a particular potential to create connectivity of pre-verbal knowledge in order to create new possibilities of thinking scientific and social problems.

**Route C: Our artistic pathway to experiencing mathematics in dance -
Commentary, video-performance and a poem**

In the following, we present our findings, bearing in mind that within the processual character of our artistic research approach, these findings are less "results", but can as much be seen as "searchings", as door-openers to yet-to-be discovered experiences and recognitions. While the findings are actually to be found within our dancing performance, we are aware that in communicating these findings we inevitably have to make at least two compromises: 1) the reader is not present at the performance but can only view the performance on video and can thus not have a reciprocal impact back on the performance, 2) as we cannot at all assume that the viewer of the video can recreate our performative experiences by merely watching, the communication of our findings in a journal article requires us to frame the video of the performance through a textual commentary.

This textual commentary will consist of extracts of the verbal reflections of our experiences during the three crucial experiential "research moments": 1) the attendance of a workshop for primary school students within the frame of the project "Learning through the Arts" (LTTA), 2) a three day workshop with the educator and dancer Angela Boeti, and 3) three days of dancing self-inquiry in a dance studio, only dancing, reflecting and discussing for four hours on each of the three days. In order to give this commentary a certain, yet undetermined, structure we arranged the fragments of our reflections in a sort of dialogue. We finally revisit this third experiential moment after displaying our performance by a video-work and in the form of a poem resulting from a "poetic inquiry" (Prendergast 2009), performed by Julia.

Reflections from the "Learning through the Arts" workshop (first experiential moment)

On the 19th of January, 2016, we participated in an LTTA workshop for primary school students, taught by the Canadian dancer and LTTA activist Nicole Fougère. LTTA brings

artists and teachers together to develop artistic methods to teach non-artistic school subjects. From January, 19th to 21st, Nicole Fougère taught mathematics, geography and sciences in different grades by means of dance. Primarily, we were allowed to take part in these workshops as observers, but were also invited to actively participate as dancers in several of the classroom activities.

Julia: The first thing that surprised me, was how much Nicole grounded the teaching unit in spoken language. It appeared to me that she used words much more to explain things than she used the body. Later I thought that this might be explained by Nicole's attempts to constantly translate bodily experience in abstract language and to re-translate abstract language into bodily experience. For me personally, this made it very difficult to indulge in the bodily sensation of the dance.

Nadine: The principle behind her [Nicole's] concept was quickly identified: From three small movements to three big movements; from individual work over pair work to presentation.

Anja: The effort to find an exact and precise movement that would match a mathematical idea(l) requires a very strong concentration in both bodily and cognitive work. Concerning the body, I was simply limited in my expression by the finiteness of my agility. Concerning the cognition, I changed imagined perspectives and tried out different axes of symmetry. This concentrated effort to find representations of mathematical contents with my whole body, is something I would rate as aesthetic experience.

Julia: As the students came together in a circle at the end of the lesson, and were asked to explain to their neighbors what symmetry and asymmetry are, I could observe how all children used their bodies for argumentation. [...] Mostly, they did not use the complete body figures [used in the lesson], but rather their fingers and feet. However, as they were asked to explain the notions to the whole class at the end, the children appeared to fall back into the regular non-dancing mathematics class. They tried to keep their bodies out of their explanations, even though I had the impression that I could spot certain gestures flashing up, however being quickly brought under control and covered by language.

Nadine: Asked about the commonalities of mathematics and dance, the children answered 'geometry', however their responses seemed to be less based on their own

recognition and more based on responses to the stipulation of the theme [symmetry and asymmetry].

Julia: I transcribed two of Nicole's statements, which I found particularly remarkable: 'Make connection between the words and what you know in the body. Because with the body you know immediately' and 'Sometimes a simple move of your body is better than what your head is thinking'.

Anja: What struck me is that at the end of the lesson, all children were quite certain that they did mathematics.

Julia: As I left the lesson on symmetry, my first feeling was that I have acquired some practical exercises that can easily be integrated into regular mathematics classes. However, and this feeling was much more intense, I was disappointed about not really having experienced what I expected. For my taste, bodily recognition and knowledge got a raw deal and were subordinated to rational knowledge. Bodily knowledge, in this lesson, was a means, a method for the end of rational recognition. Where are you, bodily mathematics? Are you more than a pipe towards ratio that needs to be forgotten on the way to expressible recognition?

Reflections from the collaboration with Angela Boeti (second experiential moment)

Driven by our experiences with the LTTA approach, we carried out an interview with the educator and dancer Angela Boeti. She invited us to her three-day dancing workshop at the Alice Solomon University of Applied Sciences in Berlin. This workshop had no direct relation to mathematics, but provided a systematic introduction to Rudolf Laban's "Laban Movement Analysis" (LMA). LMA deliberately breaks with the traditional closure of the academically codified ballet (Lampert 2007). In LMA we expected to find a form of bodily expression with which we could find a junction between mathematics and dance.

Nadine: Founded on Rudolf Laban's theory of movement, the workshop was an interplay of free improvisational dance and instructions of choreographed sequences of movement, which were based on infantile movement patterns. We always worked through different dimensions of movement.

Anja: I found one of the most important assumptions about aesthetic experience acknowledged in these three days: Aesthetic experience requires time in the first place [...] On the first day, I tried to find mathematical aspects in my movements already during Angela's dancing impulses. However, I quickly had to notice that

this required a too high degree of concentration, so that I deliberately freed myself from this "extra task" after lunch break.

Nadine: I found particularly interesting that my movements in an unfamiliar environment tended to be oriented upwards and were limited to a relatively small radius of movement. Once the group got more acquainted to each other, the movements got bigger and I started also changing the levels of movement.

Nadine: With the body, I can create tangible ranges, forms, rotations, angles, spirals, geometric bodies... Either intentionally led by the instructor or intuitively following an impulse. Intuitively initiated sequences of movement appeared to rather follow a principle of harmony and balanced the body's center with its periphery, while movements initiated by the instructor appeared to me as rather hard and mechanical.

Anja: One realization that I gained from those three days with Angela Boeti is that you actually have to go with a mathematical question into the dance improvisation, in order to – in the best case – bring up all those non-verbal aspects. I suppose that a different approach would not make sense, as I cannot erase my former verbally mediated mathematical experiences. Thus, I felt that I could not generate completely new mathematical recognition in dance.

Nadine: In relation to mathematics, my impression was that our bodies already possess an intuitive mathematical understanding. The body dances shapes in the room in custom-fit ways without bumping, it recognizes obstacles and initiates changes of direction by rotations, describes figures, like eights and circles.

Anja: Prepared in this way [by the workshop], we want to expose ourselves to an experiment, in order to try to focus on mathematical questions – as autonomous dancers. To which degree we will succeed remains completely uncertain. Exciting discussions and negotiations of meaning are awaiting us. I remain very curious.

Reflections from our weekend in the dance studio (third experiential moment)

Equipped with the experiences from both workshops, we met in a dance studio for three days in order to expose ourselves autonomously to the attempt to make mathematical experiences in dance and to find a way to communicate (mathematically) without subordinating the body to the mind. Laban Movement Analysis (LMA) hereby provided us a structural scaffold for developing an entanglement of improvisational and

choreographed dance, by distinguishing between six categories of movement: the body, the shape, the space, the effort, the phrasing/rhythm and the subject-object relation (Trautmann-Voigt & Voigt 2012, p. 135 ff.). Deliberately playing with these categories during dance allowed us to mediate the apparent contradiction between choreography and improvisation, as it allows us to combine the projecting and planning character of choreography with the retrospective (and introspective) character of improvisation. Throughout the three days in the dance studio, we found a more or less stable dramaturgy in our improvisational performances, which we then captured in choreographic cornerstones that remained stable in each new starting performance (see the introduction to the video-work below for a list of these cornerstones). These choreographic cornerstones provided the necessary frame, in which our main experiential research in improvisation could find its space. This entanglement of choreography and improvisation is visibly captured in the video work in the following section.

All speaking: During the first day we put fragments of experiences together in a new way.

Our previous research process, in which experiences were sequenced chronologically, was now broken in its linearity and experiences were linked ahistorically and dynamically. Besides that, we experienced that it was not only our verbal discussions that gained depth through our experiences but further that our bodies became acquainted and soon learned to communicate with each other through dance. We were particularly amazed by this, as we actually differ so much in our thinking patterns.

Melanie: It was fascinating to see how the bodies find each other and develop their own language.¹⁰

Anja: The security and intimacy with which we supported each other allowed me to move completely free from social and private compulsions and to open up a free palette of movement for my body.

[The sun sets and rises again]

All speaking: It became evident that realizations that we believed to be certain, often were challenged again when we started dancing.

¹⁰ Melanie participated in the research process as an observer and not as a dancer, due to her advanced pregnancy. She nevertheless participated in all research moments.

Nadine: In dance, the body goes in quest of an ideal match between the image that emerged on the cognitive level from a concept, and the emotion, which emerges through movement. This creates an inversion of abstraction over association (interpretation) into movement, which is responded to by a feeling of either fit or resistance, depending on whether I felt to have successfully modeled the mathematical concept or not. In dance, one can play through the different possibilities of interpretation with the body and thereby transform invisible inner images into visible images.

All speaking: In our reflective discussions, we tried to get to the bottom of the experiences of anxiety that emerged. We found disagreements that we could have never identified if we had only talked, and which became visible only through our dancing bodies.

All speaking: Among others, we found that some of us still lacked a bodily access to the abstractum of mathematics and that we still had different views on what mathematics actually is. Again we faced the question: What is mathematics? [...] Those of us holding diverging notions of mathematics tried to fathom out points of contact through dancing – a task that was rewarded with singular moments of success. On this second day, we again and again grasped for a shared notion of mathematics that would be commensurable with our research, and that we had believed to have already found at that point.

[The sun sets and rises again]

All speaking: After we started the day with a repeated discussion about the nature of mathematics, we tried to approach concrete mathematical statements or concepts with the techniques of improvisational dance. Concretely we worked through 'equality' ($=$) and 'infinity' (∞). While we had concerns about the danger that this analytic approach to singular abstract phenomena would limit our dance in its experiential space, surprisingly, this concern was not confirmed. On the contrary, we more and more started to question the believed truths of mathematical phenomena through dance. We recognized that a lot of the mathematics that we thought would exceed our imagination did not do so. They simply were not transcendental entities, they only existed through our imagination. We recognized that that these mathematical phenomena simply were not real, neither here nor in an ideal universe, unless we *do* them. They are results of a human practice of abstraction.

Anja: By means of the imitation of the equal sign, I came to a sequence of movements exclusively based on symmetry. I did this until I got bored and started, through an initial impulse, to play with asymmetry. However, this [occupation with asymmetry] was only apparent as I noticed that my body was actually not moving asymmetrically but always tended to balance. It was about balancing, swaying, oscillating... associations of a beam balance, seesaw, pendulum and ideas of a perpetuum mobile came up. Asymmetry and symmetry only existed in relation to one another. So did equality and inequality.

Nadine: During dancing, a permanent process of negotiating [mathematical meaning] with the emotions that were entangled with the movements took place. When these were not fitting, the search went on and singular images of movement were chained together. I hereby recognize that there cannot be absolute unity behind a mathematical notion, symbol or fact, as three different persons all have different relationships to the same concept, grounded in different emotional experience.

Anja: ...again I started [my dance] with the mathematical concept of infinity. Soon I was dissatisfied, because I could only represent two dimensions of infinity. Also, the attempt to stretch myself widely in the room (association: big bang) remained unsatisfactory. During the entire dancing confrontation with infinity I was confronted with my own limits: bodily, rationally, spatially, comprehensibly... [...] In the process, I nevertheless reached the point, where I found infinity almost at the zero position of my movement. Movements that are almost solely thought still remain visible and recognizable. My movements became smaller and smaller. I felt like a nucleus in a mass of matter. For me, it became recognizable that absolute infinity is no reality, but only a mathematically construed idea limited by the finity of my own being...

Melanie: It was thrilling to experience how mathematical concepts were initially represented in familiar forms until the dancers got exhausted by this and opened up for new dimensions. In this way the concept of infinity was suddenly wide and open and displayed a void in the dancers' movements, which then developed individually for each single one of them.

All speaking: Through dance, we could make the limits of these abstractions recognizable. This recognition was sensible by an uncomfortable feeling of mathematical phenomena in dance. At the same time, the determination of the limits of the mathematical makes visible its properties. Through a critical dancing

confrontation, concrete mathematical phenomena became realizable. This realization is first of all bodily knowledge, but can be made accessible for the cognition through reflection.

Nadine: It was not about expressing mathematical concepts with the intention of optimizing the brain, but about getting a deeper relation to a mathematical fact by establishing an emotional relation, which in turn creates a connection to one's own prior world of experience and is not isolated from the body anymore.

Anja: During dance I experienced mathematics as something cozy and small. A dancing partner, a playing partner, with whom I like to spend time – remote from compulsion and overload.

All speaking: We recognized that we had come to a workable shared notion of mathematics through our last experience [the recognition of "critical dancing confrontation" (see above)] and that we were now equipped for concrete confrontations with mathematics in dance.

The video-work of our performance

From the three days in the dance studio, an improvisational choreography emerged. This improvisational choreography represents the results of our research until that point. Seven choreographic cornerstones remained stable in each new starting performance. These seven cornerstones represent the seven crucial phases of our research process. However, the space between these cornerstones was filled differently anew by improvisation with each performance. In this way, each new performance allowed us to re-experience, re-think, and thereby re-construct the research process:

1.) in search – 2.) finding terms | finding concepts – 3.) experiencing LTTA – 4.) in search again – 5.) experience with Angela Boeti – 6.) dancing with mathematics – 7.) preliminary knowledge

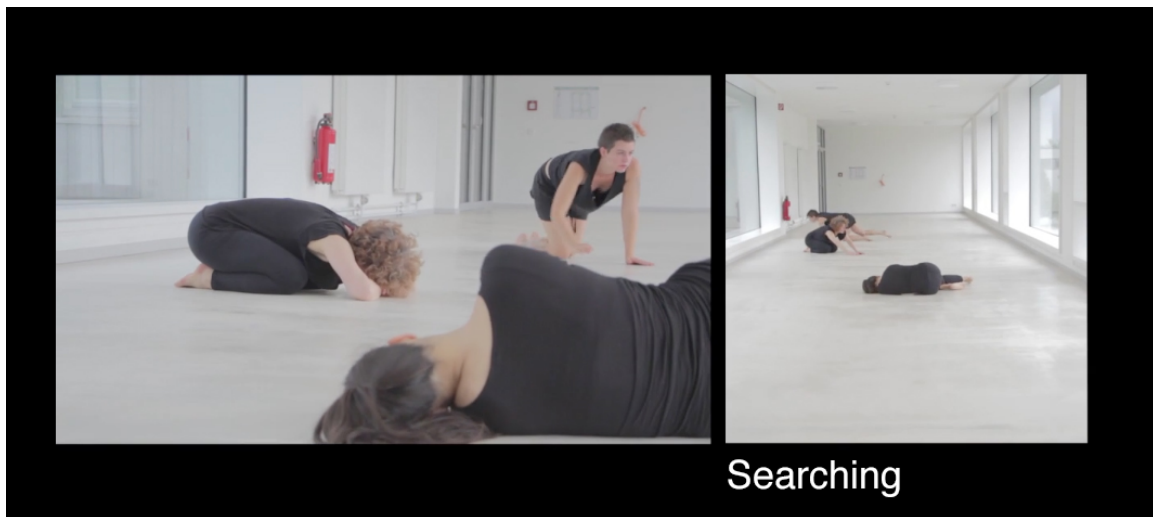
The video-work juxtaposes two of these performances, highlighting simultaneously coherences and frictions, the choreographic and improvisational character respectively. Watching the video-work may well raise more questions for the reader than it answers. However, this is exactly the objective of the video-work. The reader is invited to watch it with the attitude of the so-called "willing suspension of disbelief": Once she identifies a figure/movement/pattern that *could* stand for a confrontation with or a search for a

mathematical idea or concept, she is invited to interpret the video *as if* this was exactly the intention of the dancers, no matter whether or not it actually was.

Click on the picture, scan the QR-code, or type in the link to start the video your web-browser:



<https://vimeo.com/239840322>



A poetic inquiry of Julia's experiences in the dance studio (3rd experiential moment)

"Poetic inquiry is a form of research that can help us renew our understanding of our own lives, and make new connections with the lives of others." (Guiney Yallop, Naylor, Sharif & Taylor 2010, p. 31)

Die Mathematik zum Tanz bitten

Asking Mathematics for a Dance

<p><i>ich sehe Ihn vor mir diesen riesigen rationalen Berg der Mathematik</i></p> <p><i>ich kann mit Ihm rechnen, vertrauen kann ich Ihm nicht</i></p> <p><i>Er ist mir fremd</i></p> <p><i>unberührbar, unantastbar, nicht spürbar</i></p> <p><i>eigentlich ist Er nicht da</i></p> <p><i>eine Fata Morgana die ich erahne</i></p> <p><i>durch eine Wand, ein veralgtes Aquarium</i></p> <p><i>bringt mich zum stehen, verkleinert das selbst</i></p> <p><i>ich sage mir Er ist kein Gott</i></p> <p><i>Er ist menschengemacht</i></p> <p><i>reine Abstraktion und deshalb unvollständig</i></p> <p><i>meine Augen durchdringen die Wand</i></p> <p><i>der Berg schmilzt</i></p> <p><i>kommt in Bewegung, ich fühle es, fühle Ihn</i></p> <p><i>will Ihn spüren</i></p> <p><i>wir werden warm, körperwarm</i></p> <p><i>wir tanzen aufeinander zu</i></p> <p><i>ich kann und will Ihn jetzt erfahren</i></p> <p><i>erste Annäherungen sind verlegen unverfahren, dynamisch</i></p> <p><i>ich tanze mit meiner eigenen Mathematik</i></p> <p><i>ein Band zwischen mir und Ihm</i></p> <p><i>spielen mit Nähe, Distanz und Berührung</i></p> <p><i>da, weg, alles wird fühlbar</i></p> <p><i>im Tanz verschwimmen Ihm die grenzen, so können wir wachsen.</i></p>	<p><i>I see Him in front of me this huge rational mountain of mathematics</i></p> <p><i>I can count with Him, I cannot count on Him</i></p> <p><i>He is strange to me</i></p> <p><i>untouchable, inviolable, not sensible</i></p> <p><i>actually He is not there</i></p> <p><i>a fata morgana that i can only sense</i></p> <p><i>through a wall, a seaweeded aquarium</i></p> <p><i>makes me stop, scales down the self</i></p> <p><i>i tell myself He is not God</i></p> <p><i>He is human made</i></p> <p><i>pure abstraction and thus incomplete</i></p> <p><i>my eyes permeate the wall</i></p> <p><i>the mountain melts</i></p> <p><i>starts to move, i feel it, feel Him</i></p> <p><i>want to sense Him</i></p> <p><i>we become warm, body-warm</i></p> <p><i>we dance towards each other</i></p> <p><i>i can experience Him now, want to experience Him</i></p> <p><i>our first movements towards each other are shy, anticipating, dynamic</i></p> <p><i>i am dancing with my own mathematics</i></p> <p><i>a bond between me and Him</i></p> <p><i>playing with proximity, distance and touch</i></p> <p><i>here, gone, all becomes tangible</i></p> <p><i>in dance, the boundaries fade for Him so that we can grow.</i></p>
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Outlook and sounds from the future

Referring back to our initial research question "Is it possible to learn mathematics through dance?", one conclusion of our research experience could certainly be a "yes". However, this affirmation needs to be coupled with the amendment "..., depending on what is to be understood by mathematics". Our experiences clearly indicate that in order

to come to a positive answer to this question, the dominant notion of mathematics has to transform in the first place – and it will undergo further transformation in order to be able to integrate those bodily recognitions resulting from dancing mathematics afterwards. At this point, we are thus far from being able to make concrete suggestions about how to integrate dance as an integral part of school mathematics. However, our experiences show that dance and (school) mathematics do not necessarily stand in opposition. On the one hand, the excerpts from our reflection protocols document how the dancing confrontation with a mathematical question inevitably evokes a cognitive confrontation with the corresponding mathematical concepts (e.g. infinity) and thus contributes to cognitive mathematical understanding. On the other hand, our experiences reveal how the bodily-aesthetic work facilitates positive experiences with mathematics that hitherto appeared unlikely (or: impossible) to us: mathematics has become a "partner", we can "grow together". This second aspect touches, among others, issues of power, identity, gender and language barriers, which all have recently received much attention in the so-called socio-political dimensions of mathematics education. For us personally, the experience of mathematics in dance lays the foundation of a yet-to-be-developed mathematical education through dance. Recent developments in the field of mathematics education (see e.g. de Freitas & Sinclair 2014, de Freitas 2016, Palmer 2010, Sinclair 2009) make us optimistic that our personal experiences resonate with developments taking place elsewhere and that this article can contribute to an alternative future sound of mathematics education.

Acknowledgements

The video-work of the performance has been created by Yeni Harkányi. Thank you, Yeni, for your support.

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