The Impact of Music on Mathematics Achievement:

A Research Summary In Support of Kindermusik's ABC Music & Me

ABC Music & Me

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INTRODUCTION

Early childhood educators know the value of music in their classrooms. Most will unequivocally state that music contributes to the academic environment in ways that positively impact the whole child. A large and growing body of scientific research supports such anecdotal stories across the whole range of development. This research summary focuses on one critical aspect: the development of foundational mathematical skills and thought processes as tied to early childhood music education.

This summary begins with a brief look at how music and math skills have historically been linked. The summary then moves from theory to scientific exploration by presenting a survey of seminal studies undertaken to test the idea that music education leads to academic gains. Specifically, this summary looks at studies focused on music's impact on math abilities for children in preschool, kindergarten, and the primary grades.

Finally, this summary reveals the findings of one such research project built around a Kindermusik program that was a precursor to *ABC Music & Me.* The results of this study were published in the *Journal of Applied Developmental Psychology* and have been reviewed and commented upon by leading thinkers in the field.

This summary provides compelling evidence that a music program like *ABC Music & Me* provides symbiotic gains in essential mathematics skills. It helps to articulate what educators have always known: Music matters!

MATH AND MUSIC CONNECTIONS

Numbers, patterns, proportions, and ratios are just some of the concepts that are mastered by both mathematicians and musicians. Great thinkers from ancient times to the present have seen and used these conceptual links. For example, Pythagoras, the Greek mathematician, used math to make sense of musical concepts as he developed his ideas on music theory. Boethius, the Middle Age music expert, articulated some of his musical ideas using math concepts. And who hasn't heard about Einstein's great love of music, which he said was extraordinarily helpful to him in his work?

Thankfully, one does not have to be a genius of these proportions to benefit from music-math connections. In fact, the most beneficial time to make these links could be during early childhood. Certain brain development research shows that the early years are a prime time to make strong connections along the associated neural pathways, with music exposure as a perfect entryway (Flohr et al, 1996; Halfon, 2001; Leng et al, 1990; Leng & Shaw, 1991; Pantev et al, 1998; Peretz & Morais, 1993; Strickland, 2002).

Here's how it works. As you listen to music or make music, certain neurons in the cortex of your brain start firing. The pathways created are the same pathways that are used when you complete complex spatial reasoning tasks. The more of these pathways that are forged and the more they are in use, the stronger the connections become. Strong connections lead to easier access, which translates into better skills.

Although listening to music does give the neural network a workout, the gains in spatial reasoning skills have been shown to be very short-term—15 minutes or less. This "Mozart effect" is much longer-lasting when you engage in making music, however. Studies are showing that the attendant spatial reasoning gains can extend over months or even years (Rauscher et al, 1997; Gardiner, 2000; Hetland, 2000b). Studies focused on music for young children are also suggesting that math gains increase according to the number of years that students engage in active music learning (Gardiner, 2000), with some indication that the younger children are when they begin music instruction, the greater the gains will be.

EARLY CHILDHOOD MATH AND MUSIC

If we look at the National Council of Teachers of Mathematics (NCTM) Curriculum Focal Points and Related Expectations, we can begin to see how many opportunities exist for music education directly related to mathematics. The NCTM has clearly indicated that an isolated "skill and drill" approach to mathematics is not considered the best practice. Rather, the NCTM advocates for math learning in contexts that promote other types of thinking and problem-solving at the same time. Music is certainly one such context. Examples of NCTM Focal Points for Prekindergarten naturally linked to music understanding are listed in the table below.

Focal Point	*How It Relates to Music*
Number and Operations: Developing an understanding of whole numbers, including concepts of correspondence, counting, cardinality, and comparison	Counting beats ("how many" in a rhythmic pattern) Comparing beats ("more," "less")
Geometry: Identifying shapes and describing spatial relationships	Notation (notes are "higher" or "lower" on the staff) Organizing patterns of sounds
Measurement: Identifying measurable attributes and comparing objects by using these attributes	Tonality ("higher" or "lower") Pace ("faster" or "slower" rhythms)

(NCTM, 2008)

These are only a few basic examples. Many more links exist. Gardiner is one researcher who explicitly explores more specific early math concepts that tie to music, including a "pitch line" similar to a number line (Gardiner, 2000). He believes "mental stretching" can occur in children when music-math links are recognized and exploited. His multiple research studies have shown promising connections between progress in pitch and rhythm and progress in math.

SURVEY OF RESEARCH

In terms of scientific research designed to explore the notion that math gains occur as a direct result of music education in the early grades, by far the greatest emphasis has been placed on spatial reasoning, perhaps because the brain research discussed above has pointed to this as so promising. Spatial reasoning is a broad array of intellectual processes that come into play when you manipulate visual images in your mind and draw conclusions or solve problems about them. Humans use spatial reasoning when engaging in mental pursuits such as playing chess, devising architectural plans, creating dress designs, solving math problems, and writing or performing music.

As you will see from the following survey of the research, results are particularly convincing in the facet of spatial reasoning known as spatial-temporal reasoning. Here, the thought processes involve mentally manipulating objects (for example, flipping and turning them) in a sequential pattern.

Rauscher et al (1993) conducted the ground-breaking research in this area. Their work began with a study showing that ten 3-year-olds scored significantly better on a spatial reasoning test after music lessons. Following this pilot study, the team conducted a nine-month study with a control group and an experimental group of 3- and 4-year-olds.

Testing of spatial reasoning occurred before the study, four months into the study, and again four months later. Rigorous evaluation of the results led to this statement by the team: "…the group of children who received eight months of music lessons scored significantly higher on the Object Assembly task than the group of children enrolled in the same preschools who did not receive music training." (Rauscher et al, 1994). The Object Assembly task came from the Wechsler Preschool and Primary Scale of Intelligence-Revised and required children to arrange pieces of a puzzle to create a meaningful whole. In other words, children had to form a mental image of the whole, then arrange physical objects to reproduce that whole—a great example of spatial-temporal reasoning.

Many similar studies followed the Rauscher group's report. Hetland (2002b) conducted a meta-analysis of 15 of the studies to answer this research question: "Does active instruction in music enhance preschool and elementary students' performance on spatial tasks?" Following her work, Hetland expressed strong confirmation of the idea that there is a direct causal relationship between active music learning and spatial-temporal reasoning. In fact, the correlation among all of the studies in the meta-analysis was deemed strong enough to overcome any particular instrumentation, style of instruction, or research design. Larry Scripp, from the Research Center for Learning Through Music, New England Conservatory, comments on Hetland's study: "…these findings support the view that pre-wired connections to spatial thinking in the brain are triggered by active engagement with traditional music instruction, regardless of the intent of the music teacher" (Deasy, 2002).

These and other definitive scientific studies have led organizations that demand proof of efficacy before accepting theories to fully embrace the concept that active music learning does lead to gains in mathematics. A brochure for parents sponsored by the

National Institute on Early Childhood Development and Education states it simply: "Listening to and making music form strong connections in the brain. These are the same connections that are used to solve math problems" (Dodge & Heroman, 1999). A publication of the Arts Education Partnership puts it this way: "Nowhere in the spectrum of arts learning effects on cognitive functioning are impacts more clear than in the rich archives of studies, many very recent, that show connections between music learning or musical experiences and the fundamental cognitive capability called spatial reasoning…. In the vast literature on spatial reasoning…it is clear that mathematical skills as well as language facility benefit directly from spatial reasoning skills" (Deasy, 2002).

A STUDY PROVES KINDERMUSIK IS EFFECTIVE

We have seen the proof that music instruction leads to math gains for young children. Now the question becomes, "What type of music instruction?" Although the data seems to suggest that any type of music instruction is beneficial, educators know that a structured, well-articulated, and systematic approach to any type of instruction yields the best outcomes. It is also extremely gratifying to be able to use a specific system that has been proven by scientific research to lead to the desired gains.

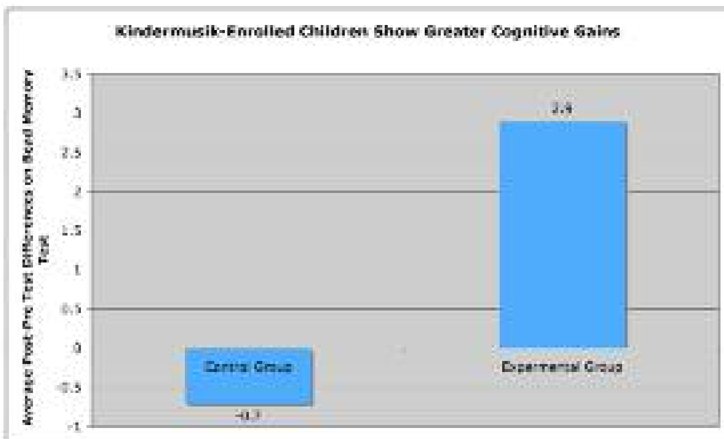
A Kindermusik program that was the precursor to *ABC Music & Me* is just such a program. Researchers used *Kindermusik for the Young Child* to answer the research question, "Does music training not involving the keyboard enhance spatial-temporal, mathematical, and verbal reasoning?", with results published in a peer-reviewed journal (Bilhartz et al, 2000). Seventy-one 4- and 5-year-old children participated in this study—half in the control group and half in the experimental group. Children represented diverse economic and ethnic backgrounds, with approximately a third representing lower income households, a third representing middle income households, and a third representing higher income households. Children attended classes at one of the following locations: two rural Head Start centers, four preschools in a small city, or a music center in the same city.

The experimental group received 30 weeks of music instruction following the Kindermusik program, which involved both teacher-led instruction and home-based learning. Researchers tracked compliance to the program's implementation guidelines and considered this compliance as a factor when the results were analyzed. In other words, the researchers were interested in finding out if increased participation in the music treatment resulted in correspondingly higher gains.

Researchers completed pre- and post-testing of both experimental and control groups to measure achievement in both cognitive and music domains. The six tests used to measure cognitive abilities were chosen from the highly regarded Stanford-Binet battery, a "widely respected measure of cognitive abilities with good concurrent validity, high reliabilities, excellent standardization, good administration procedures, and helpful scoring criteria." Separate tests (designed for this study) assessed music skills, including the abilities to a) maintain a steady beat, b) recall and reproduce rhythmic patterns, and c) recall and reproduce vocal pitches.

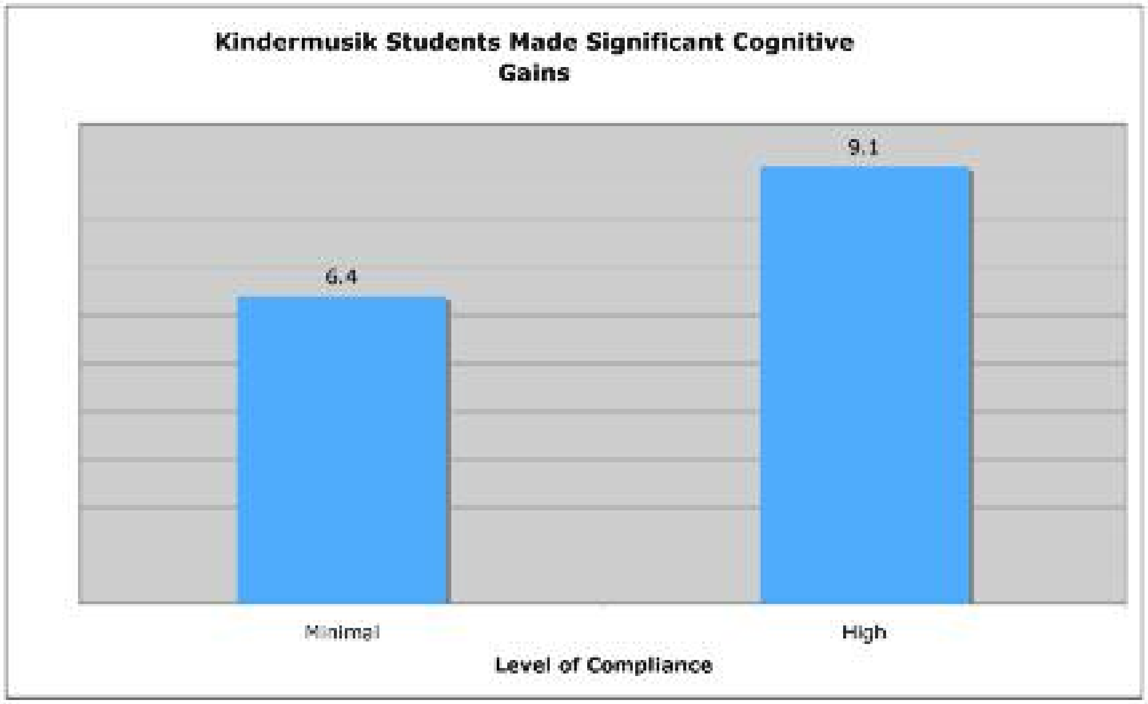
Post-testing revealed significantly larger gains among the experimental group on music outcomes and on the Stanford-Binet Bead Memory subtest. This is a visual test requiring children to recall and reassemble sequences of beads with different colors and shapes—a spatial-temporal reasoning task. As described by the researchers, the Bead Memory subtest measures the inferred abilities of: "Visual analysis; visual imagery; visual memory, sequencing, chunking, or clustering strategies; attention; flexibility; and manual dexterity."

Results showed that average Bead Memory scores were higher for Kindermusik-enrolled children than for non-enrolled children. The experimental group difference from pre- to post-test averaged +2.9 points, while the control group showed an average decline of -0.7 points. This finding and others below were consistent across all income groups.



To rule out the possibility that higher post-test scores were simply the result of having more highly involved parents (because children with highly-involved parents tend to perform better on *any* type of test), researchers not only analyzed post-test scores for the two groups, but also examined "rates of change" (improvement versus declension) variables. These variables indicate whether students in the experimental group demonstrated greater improvement than the control population during the testing interval itself. The variables presented below represent the differences between the post-test standard age score and the pre-test standard age score of participants on the Bead Memory subtest. Positive values indicate more rapid improvement during the testing interval than the national norm on the subtest, measuring whether children enrolled in the Kindermusik classes made greater positive improvement than would be expected compared to national performance norms for young children. Note that rates-of-change values greater than or equal to 4 indicate significance, indicating that the findings presented below were statistically significant.

Data was also analyzed based on children's compliance to the program, and results showed that outcomes were higher for those children who participated more consistently in school and at home. Not only were average Bead Memory rates-of-change value scores higher for those children in the experimental than the control group, but the degree of improvement increased linearly with the level of compliance or degree of music treatment. Specifically:



- Even the Kindermusik-enrolled children who met *minimal* compliance standards (N=27) showed average magnitude of improvement of 6.4 points, equivalent to an increase from the fiftieth (50^{th}) percentile on the Bead Memory subtest to above the seventy-eighth (78^{th}) percentile.
- For Kindermusik-enrolled children meeting *higher* compliance criteria (N=8), the improvement was even greater, reaching 9.1 points, equivalent to a jump from the fiftieth (50^{th}) percentile to above the eighty-seventh (87^{th}) percentile.

Overall, children participating in Kindermusik classes were twice as likely to show significant improvement in Bead Memory during the testing interval than children in the control group. And children who showed higher levels of compliance with Kindermusik classes were more than three times as likely to show significant improvement in Bead Memory than those children in the control group.

While the results of this study can be complex to understand given the technicality of the data analysis, it serves as a model for other researchers who want to back up statements of a program's true efficacy. One reviewer of this study, Robert Horowitz of Columbia University, was so impressed with the design and methodology of the research (Deasy, 2002), that he indicated that future studies should also use "compliance variables" to measure outcomes.

In summary, the researchers concluded that the results of the Kindermusik study lend support to the hypothesis that "there is a significant link between early music instruction and cognitive growth in specific nonmusical abilities." The authors explain that the Kindermusik training in kinesthetic, aural, and visualization skills produced children better able to perform abstract reasoning tasks. According to this high-quality research study, participation in Kindermusik classes significantly improved young children's spatial-temporal reasoning abilities.

SUMMARY

The link between active music learning and gains in spatial-temporal reasoning has been well-established through scientific research. Particularly well-represented among the studies are programs in the early childhood years (Hetland, 2000b). *ABC Music & Me* is based on a Kindermusik program that was part of one of the published studies revealing gains in spatial reasoning that can be specifically linked to active involvement in a music program. Therefore, implementers of *ABC Music & Me* should have assurance of efficacy. Years of scientific research in general support cognitive gains associated with early childhood music programs. And more importantly, a specific study of the Kindermusik approach points to gains in foundational mathematical skills as a result of students' regular participation in the program.

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