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Contents

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From the Editor

I hope this issue of the *Journal of Montessori Research* finds you and yours well, despite the unprecedented challenges presented by COVID-19. I have been heartened by the passionate efforts of the Montessori community to continue to serve children, families, and teachers under these difficult circumstances. I look forward to future articles based on studies that document these Herculean efforts, including a collaboration between the KU Center for Montessori Research and the National Center for Montessori in the Public Sector (NCMPS).

Since its inception, our publication has benefitted from the wisdom and contributions of NCMPS cofounder and executive director, Dr. Jackie Cossentino, who served on the advisory board for the *Journal of Montessori Research* until her death in December 2019. Dr. Cossentino was a leader in Montessori research, and we all deeply feel her loss both personally and professionally. A fitting memorial tribute and links to Dr. Cossentino's many scholarly publications are available on the NCMPS website.

I hope the articles in this issue provide a welcome reconnection to bigger ideas in Montessori education, allowing you a respite from the stress surrounding us today. We begin with an inspirational article about a program that transformed two traditional early childhood classrooms to Montessori settings within a diverse, Title I school as part of the school's dedicated commitment to social justice. The second article reports on a Critical Participatory Action Research (CPAR) study examining the introduction of six music shelf materials to address the fact that Montessori classrooms tend to emphasize developing children's visual rather than auditory senses. Finally, the third article is an intervention study examining how mathematics presentations with Montessori materials connect children's work with teacher direction based on a variation and embodiment theoretical perspective.

We are already considering manuscripts for the next issue and will be transitioning to the 7th edition of the *Publication Manual of the American Psychological Association* this fall. We ask that all future submissions adhere to the revised style guide now available in university libraries and for individual purchase. A summary of changes for the new edition is available at this link.

Sincerely,

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Montessori Education and a Neighborhood School: A Case Study of Two Early Childhood Education Classrooms

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Abstract: Project SYNC (Systems, Yoked through Nuanced Collaboration) details perspectives of a community of stakeholders committed to the enhancement of early childhood (i.e., prekindergarten through grade 3) education. Although there is a growing number of public-school programs informed by the Montessori philosophy, Montessori educational experiences often take place within affluent communities. SYNC aimed to enhance the prekindergarten through grade 3 educational experiences for traditionally underserved students by transforming two traditional early childhood classrooms to Montessori settings within a diverse, Title I school. Montessori pedagogy, curricula, and materials aligned with the school's dedicated commitment to social justice. The study, one in a series, explored the impact of Montessori education on a neighborhood school community as evidenced through stakeholder opinions, project implementation, and teacher attitudes. Project data illustrate that a Montessori educational experience created learning opportunities that supported children from culturally and ethnically diverse communities in a traditional, Title I elementary school.

Project SYNC (Systems, Yoked through Nuanced Collaboration, a pseudonym) details perspectives of a community of stakeholders committed to strengthening prekindergarten through grade 3 education. Historically, Montessori educational experiences take place in private, more affluent communities, despite an early presence within lower socioeconomic communities in Italy in the early 1900s. SYNC aimed to enhance the educational experiences for traditionally underserved students in early childhood classrooms as reported by educators committed to this work.

SYNC emerged by transforming two mainstream early childhood classrooms for 3- to 5-year-olds within a diverse, Title I school. Montessori curricula, pedagogy, and materials were the centerpiece of the classrooms and

aligned with the school's dedicated commitment to social justice. Through one in a series of research studies, project researchers evaluated impact through (a) stakeholders' opinions of Montessori education and early childhood education, (b) classroom observations, and (c) attitudes of teacher participants on the ways in which a Montessori curriculum extended student learning.

Literature Review

Montessori Education in Settings with Diverse Students

Montessori education emerged in the early 1900s with the work of Dr. Maria Montessori and her teaching of young children (Tozier, 1911). Dr. Montessori's model requires teacher training and credentialing (American Montessori Society [AMS], n.d.). As an educational model within American schools, the Montessori philosophy includes a unique presence in ethnically diverse communities, particularly among communities of color where Montessori schools have served as an alternative to traditional public schools (Mathews, 2007). In fact, public Montessori schools emerged in the 1960s and 1970s as part of desegregation initiatives in many communities.

In their work, Brown and Steele (2015) highlighted unique features of Montessori education, such as ongoing contact between teachers and students (i.e., spending 3 years together) and as a platform designed to develop "deep knowledge, mutual respect, and trust with their students of color" (p. 23). Montessori education offers an educational experience that creates opportunities for students to engage in learning opportunities that are self-directed, exploratory, and based upon individual learners. As such, Montessori education may be thought of as culturally responsive, as it is based upon classroom learners (Schonleber, 2011). Extended time together for teachers and students may reduce the misinterpretation of students' behaviors when their cultural backgrounds differ from their teachers. Further, the flexibility of Montessori experiences allows students, particularly students of color, to express and be themselves without assimilating to the norm within more-typical classroom settings. Montessori schools have created opportunities that provide students of color with education experiences that are quite different from typical learning experiences within many settings (Debs, 2016).

Because contemporary classrooms and schools include an increasingly diverse student population (Musu-Gillette et al., 2017), researchers and policy makers are in the position to consider whether and how past patterns of segregation related to resources and educational experiences are evident today (Orfield, Kucsera, & Siegel-Hawley, 2012). As a result, Debs (2016) argued for additional research to determine the role of public Montessori education as an alternative to traditional teaching settings with racially diverse students.

Put simply, research on Montessori education is complex, varied, and limited in some cases (Lillard, 2012; Lillard & Heise, 2016; Marshall, 2017). Lillard (2012) reasoned that inconsistent research findings on the effectiveness of Montessori education may be caused, in part, by the extent to which Montessori pedagogy is implemented within a classroom. Specifically, students enrolled in higher-fidelity Montessori programs had greater gains on executive functioning, social problem-solving, and academic achievement measures (e.g., reading, math, vocabulary) when compared to individuals enrolled in lower-fidelity Montessori programs.

The impact of Montessori education varies with factors such as teacher ethnicity, the integration of a culturally responsive setting, and overall enrollment of a diverse student body (Ansari & Winsler, 2014; Banks & Maixner, 2016; Brown & Lewis, 2017; Debs & Brown, 2017; Rodriguez, Irby, Brown, Lara-Alecio, & Galoway, 2005; Schonleber, 2011). The research of Ansari and Winsler (2014) and Rodriguez et al. (2005) addressed program impact based on factors such as the length of evaluations and research that disaggregates Montessori classroom experiences by race and prompts consideration of impact in new ways (e.g., Brown & Lewis, 2017; Debs & Brown, 2017; Moody & Riga, 2011). For instance, Brown and Lewis (2017) found that Montessori education could be an effective pedagogy for Black students, particularly in the area of reading, where Montessori classroom students scored higher on state assessments when compared to students in other programs.

Debs and Brown (2017) and others (e.g., Debs, 2016; Wohlstetter, 2016) offered insights into the dimensions of Montessori settings that affect programs and student success. Within their work, *success* includes both academic and nonacademic success (e.g., efficacy,

leadership, engagement with topics of race). Debs and Brown (2017) also referenced outcomes of a Montessori experience in the executive functions typically experienced by students (e.g., leadership, self-regulation) and their linkages to long-term independence and conflict resolution. Finally, learning outcomes when the Montessori model is in place revealed that traditional standardized assessments failed to address the whole child and might not best indicate impact on student learning beyond focal areas within the assessment (e.g., social skills, independence, ability to choose; Manner, 2007). These findings mirrored critiques of the limitations of common standardized assessments of learning, particularly for children of color (Crocco & Costigan, 2007; Solórzano, 2008).

Lillard et al. (2017) investigated the impact of Montessori preschool education on student learning and longer-term performance. They compared two groups of children who participated in a random lottery that assigned some students to a Montessori program and others to traditional settings. They analyzed children's performance on a series of assessments linked to academic achievement, theory of mind, mastery orientation, enjoyment of school, and executive functioning. Over the course of the study, the children who experienced the Montessori preschool performed better than did their traditionally educated peers on measures including achievement, social understanding, mastery orientation, and related scholastic tasks. The researchers demonstrated that the differences over time between children from traditional programs and those in the Montessori program decreased, despite the income differences between the groups. Their findings indicated the impact of the early childhood Montessori experiences for young children.

A larger study in South Carolina, using a quasi-experimental design conducted by the Riley Institute at Furman University and funded by the Self Foundation (i.e., Culclasure, Fleming, Riga, & Sprogis, 2018), represents one of the most comprehensive studies on Montessori education. This multiyear examination included 45 programs and evaluated features of schools, demographics, and the impact of Montessori education on academics, behavior, creativity, executive functions, and social skills. Researchers found that Montessori students were able to meet or exceed state standards in math, science, social studies, and English language arts. Further, the authors found growth in students' long-term performance in math and social studies, as well as mixed results in science. Students within the Montessori settings met or exceeded their traditionally prepared peers in executive functioning, creativity, attendance, and discipline. Though positive, executive-functioning results were somewhat mixed.

Data gathered from teachers in the South Carolina schools highlighted teacher perceptions of the fundamental classroom elements, including use of materials, assessment, and curriculum integration (Culclasure et al., 2018). Teachers cited the opportunities and some of the challenges faced in their work as Montessori teachers (e.g., standards compliance). Similar to the findings in South Carolina, SYNC offers a review of two Montessori Early Childhood education classrooms within a racially diverse, Title I school.

Systems, Yoked through Nuanced Collaboration (SYNC)

SYNC is a unique educational program that began when teachers and administrators, who had been partners in the local educational community, collaborated to influence early childhood education at Dahlia Elementary (a pseudonym). The primary goal of SYNC was to provide an educational experience for children in a Title I school under school improvement linked to state evaluation criteria in new ways within this educational setting.

Methods

Key SYNC stakeholders included State University, City School District, Dahlia Elementary School, and Conservatory (all pseudonyms).

State University

State University is a highly ranked institution within the city of Lake Town (a pseudonym). It is a doctorate-granting, research university with significant research activity. State University facilitated the partnerships and resources where SYNC aligned with the diversity focus of State University's teacher preparation mission and its connection to urban classrooms and schools. State University invited relationships with stakeholders, secured funding, navigated district requirements in concert with their Dahlia colleagues, and conducted program-evaluation efforts.

City School District
City School District is an urban school district with a diverse student body, representing more than 100 languages. Over half of the students come from ethnically and religiously diverse backgrounds. The district consists of a majority of students who are low income, and about 15% of the district's students receive special education services. Publicly available district data identify that approximately one-third of the elementary student body, nearly four in 10 of the middle-school student body, and just over one-quarter of the high-school student body are English learners.

The district provided administrative oversight on the curriculum and compliance requirements for early childhood education at Dahlia, including enrollment numbers and general assessments of student growth for 5-year-olds (e.g., Dynamic Indicators of Basic Early Literacy Skills [DIBELS]).

Dahlia Elementary School
Dahlia is a long-standing public, Title I neighborhood school. It supports approximately 550 students. Prekindergarten through eighth grade are represented at Dahlia, with multiple single-aged classrooms at each grade level. The school offers full-day kindergarten and prekindergarten. The school consists of a minority-majority student population; just over half are English learners, and nearly nine in 10 receive free or reduced lunch. Dahlia incorporates a social-justice curriculum and implements trauma-informed practices, supporting students, families, and teachers. Identification for special education services in the district typically takes place in first grade. Children in need of speech/language services are identified as early as age 3. Recent district policy changes have allowed for dedicated assessments for special education services for those in early childhood classrooms. Dahlia faculty members and the school-improvement council approved SYNC in full compliance with program operations and building policies.

Conservatory
SYNC teachers received support from Montessori education experts from Conservatory, a private, nonprofit Montessori school in Lake Town. Conservatory offers an authentic Montessori education to children, representing infants through sixth graders. Classrooms adhere to traditional Montessori multiage groupings. The student body at Conservatory is composed of 81% White children and 19% children of color. Ten percent of families receive tuition assistance. Conservatory provided the model, curricular choice, pedagogy, and professional development for in-service teachers. Conservatory employs teachers with Montessori credentials in each classroom. The teachers at Dahlia were prepared through the same Montessori teacher-education program as the teachers at Conservatory. This teacher-education program is housed within a local institution of higher education.

Project Funding
State University received a grant from a foundation linked to a private donor. The funds covered all costs for staffing, mentoring, materials, and evaluations. State University and the foundation grant funded 3 years of salary and benefits for the focal teachers and an additional 5 to 7 hours per week for each paraeducator who provided support in the Montessori classrooms. Since the beginning of the project, the district assumed full funding for paraprofessional base salaries. The foundation also supported the Montessori education classrooms by providing materials and curriculum. Because the classrooms were an addition to the extant classrooms, external funding was required for the program. If the program discontinues, teachers will resume their non-Montessori positions at the school, and the district will continue to pay their salaries.

Project Teachers
Two teachers working at Dahlia Elementary as traditional early childhood educators, teaching 3- to 5-year-olds, participated as focal teachers. Each teacher opted to participate in SYNC and understood that funding for the project would span 3 years. For existing teachers at Dahlia Elementary, the move to the Montessori classrooms for the SYNC teachers reflected a change in their assignments.

Each classroom of 3- to 5-year-olds consisted of one teacher and one paraeducator (i.e., an assistant). The first teacher was an existing Dahlia Elementary faculty member in her early thirties and a 7-year veteran of this school with a master's degree. The veteran teacher identified as Italian American and knew some Spanish. The second teacher was a first-year teacher in her midtwenties hired to work at the school during the year of project. The beginning teacher was bilingual in Spanish and identified as Mexican American.

The first paraeducator, a bilingual (i.e., Spanish and English) man in his early twenties, worked with the veteran teacher. The second paraeducator was a native Spanish speaker in her late forties who had worked in early childhood education in the past.

The teachers completed Montessori certification through an accredited, college-based, 50-credit program that they took from a local 4-year college. Coursework took place during the summer prior to program implementation. Continuing education units for course work, teaching practica, and ongoing supervision rounded out the program criteria. The specific credential was part of a Montessori Early Childhood credential from AMS.

Program coursework aligned with the college's Montessori credentialing program, and the bulk of the coursework occurred during a summer semester. Teachers also participated in biweekly seminars during the school year. Full-time teaching within their classrooms met the student-teaching requirement for the Montessori credentials. There were supervisory visits by college Montessori specialists and by supplemental support from an outside Montessori consultant.

Teachers received supervisory support as part of the practicum experiences linked to the Montessori credentialing program. Montessori-credentialed supervisors observed each SYNC teacher during practicum teaching. To provide additional support, the external consultant from out of state visited the classrooms of the SYNC teachers three to five times during the year.

In addition to the Montessori education mentoring, standard support was offered to all Dahlia educators through training designed to enhance their abilities to prepare students to meet the student-performance requirements. Specifically, SYNC students were required to complete all mandated assessments. SYNC teachers understood that the DIBELS assessment would be required of their students.

Project Students

Each Dahlia classroom included 17 to 20 students. The majority of students were Latino, comprising both immigrants and students born in the United States. American Indian, Somali, multiracial, and White students were also part of the classroom community. As a Title I school in an ethnically and culturally diverse school and district, the population of children within SYNC mirrored the school's demographics, where the majority of students were from culturally and linguistically diverse backgrounds.

Children were assigned to the Montessori classrooms, with parental approval, as an alternative early childhood education classroom within Dahlia. Deliberate recruiting efforts included invitations to neighborhood families to participate in the SYNC classrooms. Families were within the school's boundaries, so any neighborhood student had the opportunity to enroll. During the first year, the number of families interested in the program matched the capacity for enrollments. Over time, the waiting lists grew as the program's reputation expanded. Priority for enrollment within the SYNC classrooms went to siblings of current students, with second priority to neighborhood children. Overall, enrollment numbers ensured the demographics matched the community and other early childhood classrooms at the school.

The opportunity to be part of a specialized program, within the context of a traditional public school in the neighborhood of participants, was particularly appealing to families whose finances did not typically allow for private-school tuition. The SYNC families mirrored those of Dahlia in every other way.

Project Classrooms

Dahlia Elementary has four early childhood classrooms. Two of the four classrooms became comprehensive Montessori experiences for young learners (i.e., prekindergarten). The remaining two classrooms remained traditional early childhood settings. Embedded within Dahlia Elementary, focal classrooms featured a fully integrated Montessori program. All Dahlia classrooms offered full-day classes for early childhood students.

Both classrooms were fully equipped with Montessori education Early Childhood materials and curricula. The 2.5-hour uninterrupted morning work cycle, individualized lessons, materials implementation, and daily teacher observations authentically reflected Montessori principles and pedagogy. Students worked at their own pace, and teachers engaged with students one-on-one and in groups. Because of the independence and self-direction required of them, students learned

to navigate conflicts without adult assistance and understood the expectations for patience and turn-taking when materials were being used by classmates.

Table 1 summarizes the program-evaluation efforts of SYNC, which is supporting evidence for this case study (Merriam, 1988). The evaluation captured investigations of SYNC classrooms through the views and experiences of stakeholders and teachers and through classroom observations of students. Enhancing the internal validity of the research, case-study data consisted of multiple data sources (Bouck, 2011), using the classroom observations to support or contest teachers' explanations of classroom experiences, for example. To enhance the internal validity of our findings, SYNC researchers documented the case and methods so that an audit trail could build confidence in the results (Merriam & Tisdell, 2016). Case studies connect the microlevel (i.e., students, teachers) to the macrolevel (i.e., curricular choice) by offering a detailed account of the case (Vaughan, 1992).

Planning for SYNC occurred during the 2015–2016 school year, and the first year of implementation occurred during 2016–2017. Evaluation data capture key findings from the project planning stage (i.e., planning year) and the first year of implementation, when the traditional classrooms became Montessori classrooms (i.e., implementation year). Data allowed a comparison between stakeholder attitudes before and after implementation, isolating the role that Montessori education played in teaching and learning, the school community, and early childhood education at a neighborhood school. Classroom observations and teacher interviews demonstrated the actual Montessori classroom experience for teachers and students.

Attitudinal data during the planning year were generated from in-depth, in-person interviews with administrators and early childhood education specialists from State University, Conservatory, School District, and Dahlia. Forty-five-minute interviews were conducted with six stakeholders and included a series of questions (see Appendix A). Some questions were static among all stakeholders, and other questions were crafted to be particular to each stakeholder (Johnson & Christensen, 2014).

Attitudinal data were collected during the implementation phase and included electronic-survey data from six team members following 1 year of implementation (e.g., Dahlia in-service teachers, a Dahlia administrator, a Conservatory administrator). Most stakeholders remained in their positions in the planning year, allowing for re-interviews. The survey included four closed-ended questions and 10 open-ended questions. Questions addressed student-learning impact, teacher impacts, perceived effects of the Montessori curriculum on the school, and attitudes toward the collaboration fostered by SYNC (see Appendix B). The survey received an 86% response rate. SYNC researchers examined survey data using frequency distributions (Neuman, 2003), data segmentation, and coding into themes (Miles & Huberman, 1994).

To further probe the Montessori methods and outcomes with implementation, emails from the project leader to the focal teachers prompted teacher feedback immediately after the 2017–2018 school year. These follow-up questions documented narratives from teacher participants. The data highlight teachers' impressions of the impact over the 2-year Montessori model implementation. Questions addressed the Montessori model's impact on learning in the classroom and the importance of this Method and pedagogy to children in their classrooms (Appendix C). Email responses served as open-ended comments, which SYNC researchers processed and analyzed through data segmentation and coding into themes (Miles & Huberman, 1994).

Table 1
Program Evaluation for Project SYNC

Method	Timing	Participants	Sample size
In-depth interviews	Planning year	Stakeholders	6
Survey	Implementation year	Stakeholders	6
Open-ended responses	Implementation year	Dahlia teachers	2
Classroom observations	Implementation year	Dahlia students	34–40

A participant–observer conducted 120 hours of observations of student learning and teaching practices. The observer was a graduate teaching assistant whose doctoral emphases included sociocultural dimensions of education. She completed a descriptive narrative on the classroom settings. Observations occurred over 3 months at both Dahlia and Conservatory. The goal was to document the curriculum and outputs of SYNC and to gain perspectives across two sites. Within the SYNC classrooms, critical features of the observational data reflected those areas Debs and Brown (2017) had cited as influencing student success. Specifically, classroom observations focused on traditional components of Montessori education along with dedicated attention to a culturally relevant social-justice curriculum (Banks & Maixner, 2016).

Two members of the research team, who were not involved in the classroom observations, coded the observer's field notes for themes and categories within those themes (Miles & Huberman, 1994). For interrater reliability, coding occurred first separately and then together.

Findings

During the planning year, stakeholders admitted they had taken a leap of faith to forge a partnership that integrated a Montessori model into their public-school classrooms. Because of demands on educators to meet a range of assessment mandates, Dahlia educators were willing to try a model that might affect how their students would perform on future assessments. They were willing to take the chance. At the implementation stage, the survey data revealed the partners' commitment to Montessori education principles to facilitate student learning within the context of their school. Classroom observations captured daily classroom activities of students in their classrooms. Table 2 summarizes the SYNC findings of the impact of the Montessori curriculum on teaching and learning, the school community, and early childhood education. In these areas, stakeholders had planned well for issues that occurred during implementation, including teachers finding meaning in their work, educators working together for students, anticipating the importance of family connections, and growth in student independence.

Table 2
Summary of Project SYNC Findings

Stakeholder	Project stage	
	Planning year	Implementation year
Teachers and students	• Teachers present pedagogy as cooperative and comprehensive • Teachers find meaning in their work • Students exhibit fewer behavioral issues • Students learn faster • Students would be labeled less frequently	• Learning to engage cooperatively • Interactions between teachers and students • Behavior management that includes students' abilities to resolve conflicts and problem-solve • Increased student confidence
Dahlia school community	• Attentiveness to community demographics • Anticipated family involvement as part of Montessori education	• Increasing family engagement by reaching out to families to explain Montessori pedagogy
Early Childhood learning	• Potential impact on student agency • Potential impact on students and their families	• Increase in student engagement • Seeing students as individuals • Fulfillment of student potential • Language development

The Montessori Model's Impact on Teaching and Learning

Planning year

Before SYNC, Montessori education had been new to the stakeholders; however, each partner approached Montessori pedagogy with an attitude of excitement. Each stakeholder expected that Montessori education would have a positive impact on student learning. Montessori education would present teachers with another teaching method for aiding student learning that, according to a stakeholder, comprised a "comprehensive curriculum and pedagogies." According to another stakeholder, Montessori classroom experiences would help teachers to find even more "meaning in their work." When imagining how Montessori education would affect students, stakeholders said they expected Montessori classrooms would involve "less labeling of kids," bring "opportunities for each child," allow "kids [to] learn faster," and "reduce behavioral issues."

Stakeholders were overwhelmingly positive about SYNC, but, at the planning stage, some individuals expressed concerns about whether it was possible to demonstrate SYNC's impact on teaching and learning. They felt that impact data might be needed for SYNC to be determined successful and to receive continued support. One stakeholder said that the effects of educational initiatives take years to appear in outcomes, such as in standardized testing scores.

Implementation year

Classroom observations reflected the influence of the Montessori education philosophy on daily teaching and learning. As shown in Table 3, observed themes included nuances in behavior management, classroom culture, instruction, and the roles of students and teachers. These larger themes emerged from specific practices observed in the classroom. When teachers engaged in behavior management, observations indicated that teachers in the Montessori classroom desired a quiet classroom in which students could perform their individual work and avoid conflict in class. Observations of the classroom community indicated that students were interested in each other's individual work, participated in casual conversations, and were relating to one another in their decisions to share, volunteer, and/or make

Table 3
Classroom Observation Themes

Theme	Most common classroom practices for theme
Classroom culture	Behavior management • teachers promoting a quiet classroom: students using soft voices and hand raising • teachers managing when students were doing what they wanted • students arguing or fighting Classroom community • students interrupting lessons because of interest in what others were doing • students rejecting sharing • students volunteering for tasks • students and teachers enjoying casual conversations • students making peace with each other
Instruction	Teacher interacting with an individual student and delivering lessons individually
Role of students	Students correcting one another's behavior and speech, casually or in a lesson
Role of teachers	Classroom management • asking students to find work • staying close or at a distance depending on whether it is an individual lesson or a group lesson • organization • encouraging students and giving compliments • keeping order during work time

peace. Observations of classroom instruction revealed a dynamic classroom, where students often interacted one-on-one with their teachers. Peers interacted with one another too. Students were observed educating one another through correction, either casually or as part of a lesson, as a form of peer learning. While managing their classrooms, teachers assisted students with their work and organized materials.

At the start of SYNC, teachers indicated a need for additional Montessori education support in the classroom to further facilitate student learning. For example, teachers cited curriculum materials as a necessity. Teachers began to see the effects of SYNC, particularly in the area of student confidence, after they received increased mentoring support. When asked to discuss the impact of Montessori education on her teaching, the beginning teacher responded,

> *My student developed the habit of practicing the Movable Alphabet every day by herself. The phonemic awareness clicked. She was so proud of herself. . . . I told her, "See, you worked so hard every day and you didn't give up, and now it doesn't feel hard anymore!"*
>
> *She would run over to us and tell us about her triumph: "Ms. X asked me to practice the Movable Alphabet every day—it was hard, but I didn't give up, and now I am a really good reader!"*
>
> *The students listened to her and became more motivated to practice different works themselves. My student's Montessori education instilled a strong work ethic, perseverance, and confidence.*

The value of this level of student persistence demonstrated the ability to continue, even while struggling, to use Montessori education materials until she mastered the skill. Important goals of Montessori education are for students to challenge themselves, to not be afraid to try difficult tasks, and to take academic risks and be comfortable with failing and trying again (Lillard, 2005).

The Impact of Montessori Education on the Dahlia Elementary School Community

During the planning year, educators came together to examine how a commitment to student learning through Montessori education might unfold within their community. With time, stakeholders observed the effect of Montessori education on the school community.

Planning year

From the onset, SYNC considered the school's mission and goals. One stakeholder articulated that SYNC was a chance to help a "struggling school." Two additional stakeholders noted that "at-risk" students could benefit from Montessori education, as this approach could help students "at all income levels" to learn. Another stakeholder noted that the inclusion of Montessori classrooms in a public school promoted more "authentic" parent involvement, as Montessori education "affects the family and extended community."

SYNC met Dahlia's needs through dedicated attention to the demographics of the community and the diversity of students' languages. During the planning year, stakeholders anticipated that Montessori education might influence language-skill development because teachers engaged with curricula that supported language based upon each child's learning needs. A stakeholder said, "A child who doesn't speak English or doesn't speak English well can work with the materials and be grasping concepts and learning just through their interaction with the materials." Because Montessori pedagogy uses concrete materials or silent demonstrations that do not always require understanding language or an advanced understanding of English, the methods did not rely on the English language competencies of each learner. Therefore, children's experiences did not solely depend upon their English competencies.

Implementation year

All stakeholders reported that SYNC met Dahlia's needs, including family engagement. Three stakeholders mentioned a success of the partnership that related to family engagement. A stakeholder reported the partnership "had a positive impact on the students and their families as well as the school and community." Family engagement was not without challenges. One stakeholder remarked, "Parents were unsure of what Montessori [education] was, and [there was a] fear of the unknown." Collaborators, however, generally felt that "family engagement has been a big [success of the partnership]; families, students, and the community are immensely excited about our Montessori program."

Montessori Education's Impact on Early Childhood Learning

Stakeholders articulated a number of perceived benefits when planning the details of SYNC. As a primary benefit,

all stakeholders believed that SYNC could positively influence early childhood learning.

Planning year

Stakeholders viewed Montessori education as having a positive effect on early childhood education. Two other stakeholders said that participation in SYNC and exposure to Montessori education was beneficial for learners as it was "student centered," "hands-on," and a "thoughtful way" for students to "work from where they [were]." Another collaborator said that Montessori education was "unique in that it allows for developmental appropriateness, it allows for independence on the part of students."

Implementation year

All stakeholders reported the implementation of Montessori education to be successful and impactful. For teachers, the philosophy, curriculum, and instructional practices enhanced their ability to inform student learning. One stakeholder shared, "The uninterrupted work cycle of Montessori [education] really supports students in remaining engaged with their education.... I was able to see how my 3-, 4-, and 5-year-olds are able to be productive but at the same time know when they need a slight challenge." Another stakeholder noted that, through SYNC, students had learned "how to concentrate, follow logical sequence, keep materials orderly, and complete a cycle of activity."

During SYNC's implementation, one teacher reported that "students changed and became their own person." Stakeholders expressed the importance of students who "see themselves (more often than not) as agents of their own intellectual pursuits." The teachers said the focus on the individual resulted in "more opportunities for the students to express their own ideas and feel free to learn at their own pace" and "the ability to see what [the] student's full potential was."

At the end of the first year of SYNC, participating teachers reflected on the year. Both teachers demonstrated a feeling of satisfaction in their work and in the accomplishments of their students, and both shared specific areas of growth in their students. They identified explicit examples of how their students' skills developed over time. Equally significant were responses that highlighted student independence and ownership of their learning.

A closer look at how teachers described their students' growth also revealed differences. As may be expected for a novice, the first-year teacher aptly identified student growth as linked to particular learning tasks within the Montessori classroom setting. Her attention often focused on the pedagogical impact of Montessori education on student learning:

> *I could sense* [the student's] *frustration because this work was hard for her, but I encouraged her by telling her it was making her a better reader. For example, within a few weeks of routinely practicing together, she could correctly identify the beginning and ending sounds of a word. I would remind her of this progress, and she would agree to do the work with me. Then within a few more weeks she was able to identify the beginning, ending, AND middle sounds with a little assistance.*

The veteran teacher also cited the importance of students' development, as well as more broad-based outcomes, with specific references to her students' personal growth as learners. For example, when asked about the ways in which the Montessori model influenced her work, the veteran teacher responded,

> *Montessori education has opened numerous teaching possibilities, one of those being starting each school year with Grace and Courtesy lessons to set the tone of the classroom, so that everyone is on the same page and that they are able to build relationships with each other, their peers, and with families. These components are great because they feed positive communication skills, and the repetition component which allows them to know what is going to happen throughout the day.*

Teachers' reports highlighted both specific, positive dimensions and relationship building on multiple levels.

The beginning teacher's perceptions primarily linked to students' skill acquisition as a means of encouraging confidence and mastery. She often referenced the assessments required by her school when citing her students' performance.

> *All kindergarten students were required to take the DIBELS assessment three times a year. On the midyear assessment in January, [a student] did as well as her classmates in all categories except for phonemic awareness. For example, I would ask her to say the*

sounds in the word cat *and she would say "cod." She could identify the first sound correctly but not the middle or the ending sounds. This lack of phonemic awareness really hurt her score and she was considered red, significantly below grade level.*

When asked to describe why Montessori education matters for their students, the veteran teacher responded,

It matters to my kids because it shows them that there is more than just one way to learn. For example, having the children move at their own pace is wonderful because it prepares them for the future and the fact that not everyone moves at the same speed, and that is okay. . . .

The curriculum allows them to have fun in the classroom. Further, all of the different areas that a Montessori classroom includes can and will trigger interesting questions and conversations.

The Peace corner component allows children a space where they can cool off. It is very beautiful when you see a child make the choice to go to the Peace corner on their own to relax versus having them explode and being sent to the office.

Naturally occurring questions and the ensuing conversations in the Peace corner often centered on identity. Discussions of a student's hijab or of being Mexican prompted the inclusion of regular dialogue among students and teachers on similarities and differences. Specific conversations included racism, with one teacher–stakeholder saying, "[My students] have not really learned to advocate for themselves or others." When explaining Montessori education as part of a Title I school, another stakeholder said, "The Montessori curriculum has created an environment for students to share their particular life experiences and backgrounds."

Conclusion

SYNC educators offered students opportunities to increase learning through resources not typically available to public-school children in this district. As one stakeholder reported, "We are providing education to a population of students that usually do not have access due to the fact that most schools are private." SYNC demonstrated the power of a Montessori experience for children from a traditionally underrepresented community of learners. Program features fostered peace, justice, and individual identities. Central to Montessori education at Dahlia were respect for self, others, and the environment.

Teaching and Learning in SYNC

The development of a strong work ethic, perseverance, and confidence are important goals for Montessori education. The Montessori classroom provided a safe place where children engaged in Montessori experiences that included independence and exposure to lesson content over time. The individualized nature of the Method allowed each child to work at his or her own pace, rather than having to move to the next lesson prematurely. Because all children worked on their own activity, each student continued to work on a skill or concept as long as necessary and often felt a sense of accomplishment following concept mastery. The teachers had the impression that this feeling motivated children to work hard in the future and to persevere when a concept proved difficult.

Although there were general differences between the two teachers on the impact of the Montessori model on students' experiences, a common theme emerged. Specifically, teachers' comments described their classrooms as having a culture of cooperation and a place where problem-solving actions were often initiated by students. While still 3- to 5-years-olds, students regularly demonstrated understanding of the importance of working with others. These curricular dimensions allowed teachers to move beyond general curriculum integration. For example, within the Dahlia classrooms, the Peace corner, a designated space as a component of the classroom, supported students' self-regulation. Through group Grace and Courtesy lessons, students learned to resolve conflicts independently, rather than relying on a teacher to mediate. The specific ways in which Montessori pedagogy encouraged conflict resolution among the diverse student body was an unexpected finding at implementation.

The Community and SYNC

As a dimension of school culture, SYNC influenced the Dahlia community. For example, the opportunity for classroom teachers to engage in an alternative curriculum through SYNC reflected a responsiveness to the culturally and linguistically diverse needs of their students. Curricular flexibility let teachers and children embrace their racial and cultural identities and learn how to respect others' identities.

Project findings underscored the realities of the contextual demands educators faced in a Title I school and of the implementation of a Montessori program within an elementary school setting. In a public-school classroom, SYNC teachers aligned their work with the expectations of all teachers by attending to the professional tasks of instruction, assessment, and assistance. As public-school educators, SYNC teachers were required to meet school, district, and state requirements for student learning. However, with its flexibility and responsiveness to the diverse backgrounds and experiences of the students, SYNC provided a venue that afforded teachers the chance to create opportunities for all learners. Teachers implemented a culturally relevant curriculum in coordination with pedagogy reflecting antibias and antiracist practices. These practices aligned with the school's fundamental commitments to social justice as part of its community. Reflecting this ethos, the supplemental texts, art, and stories used in SYNC classrooms reflected the cultures and backgrounds of SYNC students and emphasized the school's value of acknowledging and celebrating its students. Adding to the curriculum, some of the teachers and paraprofessionals shared the same backgrounds of some students, which demonstrated a recognition and valuing of home languages.

There were operational challenges in the planning and implementation of SYNC that required stakeholders to communicate directly with one another. For example, project stakeholders responded positively to SYNC's goals by incorporating more Spanish and bilingual lessons and instructors who were able to provide language support for the children, thereby responding to the changing demographics of today's communities, where multiple languages may be spoken.

Past research on Montessori education attended to student demographics and measures of effectiveness through standardized assessments of performance. Standardized assessment of SYNC students' academic achievement was not within the scope of this research. An independent evaluator and the school district reviewed student-performance data, and early findings indicated performance trends that met, and in some cases exceeded, those seen in children in traditional classrooms. A more thorough reporting of these results is planned for a future study.

As with all case studies, limitations may include a lack of internal validity, reliability, and generalizability (Merriam & Tisdell, 2016). However, SYNC provides a snapshot of a unique project that led to open discussions of the types of academic experiences that could provide learning linked to individual identities and narratives. The feedback from stakeholder experiences and the observations of classrooms highlighted the complexity of life in classrooms and the unique ways in which Montessori education informed the Dahlia community. For SYNC teachers, the implementation of the Montessori tenets of decision-making, problem-solving, and critical thinking in the classroom resulted in individualized learning experiences for all children.

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Appendix A: Stakeholder Planning Year Interview Questions

1. What is your role in Project SYNC?
2. What do you feel is the primary benefit of SYNC?
3. The SYNC website is a tool used to spread the program to different schools. What do you hope others will learn from this project?
4. What are the roadblocks that could come or already have come into play that might negatively impact the goals and/or implementation of SYNC?
5. Do you think Montessori principles work for all school environments? Why or why not?
6. What do you think the Montessori classrooms will bring to the elementary school?
7. In what ways does SYNC promote responsive education, one of its goals? In what ways does SYNC reach all learners, another goal?
8. Where do you see SYNC having the greatest impact on student learning? Why do you say that?

Appendix B: Stakeholder Implementation Year Questions

In thinking about this past, first, year of the implementation of Project SYNC, where Montessori classrooms have been created in the public school of Dahlia Elementary, please answer the following questions by selecting a category or filling out the text boxes below each question.

1. Name (optional): _____
2. Which of the following are you **primarily** affiliated with?
   - Dahlia Elementary
   - Conservatory
   - State University
3. Overall, how satisfied are you with Project SYNC?
   - Extremely dissatisfied
   - Somewhat dissatisfied
   - Neither satisfied nor dissatisfied
   - Somewhat satisfied
   - Extremely satisfied
4. What are the **benefits** of SYNC?
5. What are the roadblocks that have come into play that have negatively impacted the implementation of SYNC?
6. In what areas has SYNC had the greatest impact on student learning, if any? Why do you say that?
7. In what areas has SYNC had the greatest impact on teachers (either those teaching in the Montessori classrooms or those who have participated in Montessori training), if any? Why do you say that?
8. How successful has the inclusion of the Montessori philosophy been in the environment of a diverse, Title I public school?
   - Extremely unsuccessful
   - Somewhat unsuccessful
   - Neither successful nor unsuccessful
   - Somewhat successful
   - Extremely successful
9. In what ways, if any, do the Montessori principles assist in the examinations of race, racism, equity, access, and multicultural education?
10. How successful has the inclusion of the Montessori philosophy been in the environment of a school with a social-justice curriculum?
    - Extremely unsuccessful
    - Somewhat unsuccessful
    - Neither successful nor unsuccessful
    - Somewhat successful
    - Extremely successful
11. Please provide specific examples of how the social-justice emphasis has been included in the curriculum at Dahlia.
12. How do students respond to the social-justice adaptations to the curriculum at Dahlia?
13. What have been the successes, if any, of the partnership between the State University, Dahlia Elementary, and Conservatory?
14. What have been the limitations, if any, of the partnership between the State University, Dahlia Elementary, and Conservatory?
15. What would you like to see done differently next year to improve SYNC, if anything, in the following areas?

- Teacher selection and training
- Student recruiting into the Montessori classrooms
- Meeting the needs of the diverse school community
- Work with families
- Communication between State University and Dahlia Elementary
- Mentoring
- Adequacy of supplies and related materials
- Attention to language (English and non-English)
- Other _____

Appendix C: Classroom Teacher Open-Ended Responses

1. Could you tell me a bit more about why the Montessori model has impacted the stories you told me about?
2. What is it that Montessori added or made possible?
3. Why does Montessori matter for the children in your classroom?

A Child-Directed Music Curriculum in the Montessori Classroom: Results of a Critical Participatory Action Research Study

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Keywords: *music, curriculum, Montessori, action research, early childhood*

Abstract: Maria Montessori strongly advocated for music learning to be fully integrated into the classroom; however, many Montessori classrooms are dominated by materials aimed at developing children's visual sense. The purpose of this critical participatory action research (CPAR) study was to address this perceived learning disparity by developing and implementing a curriculum that is consistent with the Montessori approach, child directed, and focused on sound examination and music learning. We designed six shelf works and offered them, over the course of 6 CPAR cycles, to 20 3- to 6-year-old children attending a Montessori school. Findings from qualitative and quantitative data indicate that the children received the works positively, chose to engage with them, became more confident in their musical tasks over time, showed signs of deep concentration and attention, and demonstrated consistent performance across similar tasks related to perception and cognition. We conclude that the presence of these 6 curricular works began to disrupt the perceived learning disparity we identified; however, more can be done to understand and change the classroom practices that support that disparity.

Maria Montessori posited that sense education aimed at "the acquisition of a fineness of differential perception" (Montessori, 1912/1967, p. 178) is a necessary component of a child's education. Such education prepares children for encounters with their environment and all other areas of learning to come (Montessori, 1912/1967). Essentially, Dr. Montessori believed that sensory education is the foundation for an individual's successful navigation of life and learning.

Though Dr. Montessori's belief in sensory experience and development is still apparent in Montessori education

today, support for sensory development fails to exist in balance with other developmental domains within classrooms. As an illustration, 28 Montessori trainers, representing Association Montessori Internationale/USA and the American Montessori Society, identified the Sensorial materials necessary for a Montessori classroom (Lillard, 2011). Only one of the 17 identified materials (6%) pertained to sound perception (i.e., Sound Boxes/Cylinders), one to smell (i.e., Smelling Bottles), and no taste materials were identified as necessary. The majority of the materials (59%) relied upon and developed the visual sense (Lillard, 2011).

This imbalance is likely an outcome of a long societal evolution toward the favoring of the visual sense. In arguing for art educators to move beyond a purely visual approach to their work, Bolin and Blandy (2003) noted Classen's (2002) work in exploring "ways that enlightenment philosophers, industrialists, and scientists were mesmerized by the visual to the detriment of the other senses.... Smell, touch, and taste were eclipsed in importance as the visual became associated with objective reality" (p. 254). Bolin and Blandy (2003) argued that such an imbalance is discordant with our current multimedia world and detrimental to students:

> *If art educators continue to privilege visual objects and/or visual experiences . . . our students and the field will be susceptible to manipulation through our other sensory modalities. In this, our field will continue to perpetuate the disciplinary and sensory boundaries that fail to encourage a holistic and systemic understanding of experience.* (p. 247)

Music educators have long held that the development of the auditory sense and musical capabilities is a right for all students because of music's "ability to communicate the ideas and emotions of the human spirit" (National Association for Music Education [NAfME], 1999, para. 4). Further, research has shown that quality musical engagement can encourage singing development (Dansereau, 2011; Salvador, 2019), rhythmic capabilities (Ilari, Fesjian, & Habibi, 2018), and tonal skills (Gerry, Unrau, & Trainor, 2012) in young children. It has also been shown to have a positive effect on young children's executive function (Gerry et al., 2012; Joret, Germeys, & Gidron, 2016; Moreno et al., 2011), self-regulation (Winsler, Ducenne, & Koury, 2011), social-emotional development (Gerry et al., 2012; Menzer, 2015; Ritblatt, Longstreth, Hokoda, Cannon, & Weston, 2013), and language acquisition (Bolduc, 2009; Gromko, 2005; Magne, Schön, & Besson, 2006).

The key role music education plays in children's lives and development was reflected in the recent signing of the Every Student Succeeds Act (ESSA), which identified music as part of a "well-rounded education" (ESSA, 2015, Title VIII, Sec. 8101); however, NAfME reported that more than 1.3 million elementary-aged U.S. children do not receive any music education in school (NAfME, 2018). This is particularly distressing given that early childhood, defined here as birth through age 8, has been shown to be a key period for musical development (Cho, 2019). According to Habib and Besson (2009), the time before age 7 is likely a "'sensitive period,' . . . beyond which music-induced structural changes [to the brain] and learning effects are less pronounced" (p. 279). Further, it is thought that music aptitude, meaning one's potential to learn and understand music, is in a developmental state during early childhood and that this potential is affected by the quality of an individual's early musical experiences (Gordon, 2013). Stated another way, children's early musical environment is an important determinant of their potential to be musical throughout life.

Recognition of the importance of music learning for young children has resulted in a commitment on the part of some early childhood centers to provide music education for their students; however, such education experiences tend to be teacher directed (often in the form of group singing; Nardo, Custodero, Persellin, & Brink Fox, 2006) and not aligned directly with the independent, child-directed learning that characterizes the Montessori approach.

Additionally, music education tends to occur at a separate time, apart from the daily classroom work of the children (Nardo et al., 2006). This practice runs contrary to Dr. Montessori's belief that "music was an inherent part of [her] teaching, having a place alongside mathematics, language arts, and science, never relegated to being extras or optional activities" (Rajan, 2016, p. 236). Dr. Montessori believed that without music learning, children would be unable to "perceive the delicate complexity of sounds" (Montessori, 1912/1967, p. 206). Consequently,

she created materials such as Bells and Sound Cylinders[1], which are still in use today in varying degrees. Despite these efforts, however, Dr. Montessori expressed concerns as to how children might learn music in a way that truly embodied her Method. She wrote:

> *The rigorous scientific education of the sense of hearing is not practically applicable to the didactic method. This is true because the child cannot* exercise himself through his own activity *as he does for the other senses. Only one child at a time can work with any instrument producing the gradation of sounds. In other words,* absolute silence *is necessary for the discrimination of sounds.* (Montessori, 1912/1967, p. 204)

Dr. Montessori herself noted (1912/1967) that the didactic materials related to the sense of hearing were limited in their ability to encourage deep and independent learning of sounds and music. Further, despite developments in technology that allow children to engage with musical sound without disturbing others (i.e., headphones), Montessori music materials and curriculum seem not to have evolved to reflect changes in our world. Consequently, music education remains relegated to a particular time in the day, if it is provided at all, and/or consists of teacher-led activities within a classroom that is dominated by materials aimed at developing the visual sense. The purpose of our study was to address this perceived learning disparity in the Montessori classroom by developing and implementing a curriculum that is child directed and focused on sound examination and music learning. Specifically, we sought to answer the question "How is a curriculum of music- and sound-based works developed, implemented, and received in a Montessori classroom?"

Literature

We have some sense of the effects of a Montessori curriculum on phonological awareness (Franc & Subotic, 2015), social skills, theory of mind, and story writing (Lillard & Else-Quest, 2006; Marshall, 2017), as well as on executive function, reading, math, vocabulary, and social problem-solving (Lillard, 2012; Marshall, 2017). There have been few empirical investigations, however, related to music within a Montessori classroom. In a study on the effects of music-enriched Montessori instruction on elements of mathematical achievement, Harris (2007) assigned 200 three-, four-, and five-year-olds from Ontario, Canada, to an experimental or control group. The experimental treatment consisted of a music program designed to teach musical concepts of pitch, duration, timbre, and form, while also encouraging listening, vocal, and motor skills. The control group received traditional Montessori instruction without the musical-enrichment component. The experimental group significantly outperformed the control group on a test of early mathematical skills.

In a descriptive study, Rajan (2016) queried 36 Montessori school directors from eight U.S. states about the role of music in their schools, their personal beliefs about music and children's development, the challenges of teaching music, and their beliefs regarding the importance of music within the Montessori curriculum. The directors reported valuing music education in their schools but also cited limitations pertaining to resources and faculty. Musical experiences in the schools consisted of listening activities during class time and music as a facilitator of transitions. During independent work within the classroom, teachers often played background music to create ambience. Though the directors believed that music was integral to Montessori education, only 28 schools employed a music specialist, and fewer than half offered daily music instruction. Rajan did not report any instances of the inclusion of music education in the children's independent work.

Although there is not a large body of research related to music and Montessori education, nor are there studies that pertain to Montessori materials aimed at musical development, there is research on children's musical behaviors that occur outside of teacher-led instruction. Most of this research relates to children's participation in a music center, which typically consists of a partitioned section of the classroom containing instruments and recordings for children to freely explore (Kenney, 1997). Such centers have been shown to be quite prevalent in early childhood settings. For example, after surveying 293 early childhood centers, Nardo et al. (2006) reported that

[1] The Montessori Bells, when ordered, produce a scale; they were designed to encourage children to discriminate among pitches. The Sound Cylinders were designed to encourage children to discriminate among unpitched sounds created by shaking cylinders containing various materials.

almost half of them offered children opportunities for free play with music materials several times a week, 59% of centers provided a listening center with headphones, and 56% offered a dedicated music center. Similarly, Rajan (2017) found that 88% of 178 surveyed preschool teachers within a large state in the Midwestern United States made classroom percussion instruments (e.g., maracas, drums, bells, shakers, rhythm sticks, triangles, xylophones, egg shakers, bongos) available for children to explore throughout the day via music centers or prop boxes. There is no evidence from either of these studies, however, that the materials available to children were intended to move beyond exploration to encourage consistent and sequential learning about sound or music.

In an effort to study children's behavior within music centers, Berger and Cooper (2003) documented children's play at music centers during 10 weekly music classes for parents and children. The classes were held at a university rather than within a preschool, and the researchers engaged with the children in the music centers upon request. Berger and Cooper did not provide a description of the music centers; however, based on brief summaries of play episodes, it is evident that they contained books, puppets, and instruments that are often provided to preschoolers (e.g., drums, mallets, triangles, xylophones). Three themes emerged from the analysis: while in the music centers, children engaged in unfinished play (i.e., indications that the children wished to continue the musical play), extinguishing play (i.e., play behaviors obstructed by adults), and enhancing play (i.e., musical play that was encouraged by adults). It should be noted that the aim of the music centers was to encourage free musical play and exploration of sound sources, rather than specific child-directed music learning.

Sims, Cecconi-Roberts, and Keast (2011) were also interested in understanding how children freely responded to a music center, but in this case, it was a listening-only center. The researchers provided three cassette players, headphones, and tapes of two musical pieces to 4- and 5-year-old children ($N = 37$) over 8 days, and tracked their behaviors. Sims et al. were struck by the popularity of the center (over 100 visits during the 8 days of data collection) but acknowledged a possible novelty effect. The children spent an average of 12.15 minutes per visit to the center; visits ranged from 2.03 to 40.0 minutes, indicating that the response to the center varied quite a bit by child. The researchers concluded that the children found value and meaning in the listening experiences.

Music centers were conceptualized somewhat differently by Baker (2008) in a study of kindergartners through sixth graders living in Tasmania, Australia. The centers were open to free exploration and self-paced, as those cited before; however, Baker's centers had a distinctive problem-solving component and reflected Wiggins's (2001) emphasis on performing, listening, and creating music. For example, in one center, students read a poem and then created sounds for the two main characters of the poem. After doing so, they were tasked with notating their sounds, choosing between traditional music notation (i.e., notes on a musical staff) or graphic notation consisting of symbols and/or pictures. The students then altered the sounds based on the activity in which the character was engaged, infusing an aesthetic component into the sound creation. Finally, the students read the poem aloud while incorporating their created and manipulated sounds. Eighteen such centers were piloted with children over a 2-week period, and the children completed questionnaires regarding their experiences with the centers. Baker concluded that "participants overwhelmingly enjoyed the process of completing learning centers, that learning about learning through the centers was strongly reported, that some musical learning was evident and that problem-solving in this context was understood variously by participants" (p. 29).

As has been shown, Baker's (2008) conceptualization of music centers for elementary-aged children as opportunities to solve problems is anomalous in the literature. More commonly, music centers for preschoolers are not goal oriented, nor do they reflect an intentional curriculum of music learning. According to Hornbach (2005),

> *free musical play is often undertaken in music centers in which children are left without supervision to explore musical instruments or other manipulatives; though exploration is important, if children do not yet have the vocabulary or a sense of rhythmic and tonal syntax for contextual music making, free play in music centers may only be exploration. This musical vocabulary may be provided to young children through their participation in a group music class.* (p. 11)

While the development of rhythmic and tonal syntax for contextual music making may occur during teacher-directed music classes, the exclusive implementation of this approach betrays the independent, child-directed principles of a Montessori approach. Further, while musical play is inherently valuable, and exploration of sounds and musical instruments within music centers may be useful, an exclusive implementation of this approach deprives children of the opportunity to develop their musicianship through intentional and sequential musical engagement. Consequently, we have concluded that a child-directed curriculum that is consistent with the Montessori approach, aimed at the development of young children's musical perception and cognition, and designed to balance the strong presence of visual stimuli in the classroom is needed.

Method

This study took place in a Montessori school where Author 2 (Brooke) is a Primary teacher. Author 1 (Diana) is a music-teacher educator and early childhood music researcher at a nearby university and has two children who attend the school. The study was conducted under the auspices of the institutional review board at Diana's university.

The development of a music curriculum was an outcome of several casual, initial conversations between Diana and Brooke, and of Brooke's expressed interest in enhancing the musical offerings in her classroom. Brooke currently has the Montessori Sound Cylinders available in her classroom. The school owns one set of Montessori Bells, which are available at the discretion of the music teacher, when the children attend music class once each week.

Design

We chose to engage in a critical participatory action research (CPAR) study because we sought to disrupt the disparity we perceived within the Montessori classroom, which favors a visual–tactile approach to Montessori education and the corresponding senses, ways of knowing the world, and methods of expression. Kemmis, McTaggart, and Nixon (2013) described action research as "practice-changing practice" (p. 2) and CPAR as rejecting

> *the notion of the "objectivity" of the researcher in favour of a very active and proactive notion of* critical self-reflection—*individual and collective self-reflection that actively interrogates the conduct and consequences of participants' practices, their understandings of their practices, and the conditions under which they practice, in order to discover whether their practices are, in fact, irrational, unsustainable, or unjust.* (p. 6)

We began with a series of meetings in which we identified our shared concern, our public sphere, and our ideas for action in accordance with CPAR (Kemmis et al., 2013). Our shared concern was the perceived disparity in the Montessori classroom, which marginalized the role of sound in children's learning and expression. Our public sphere (i.e., those invited to join us in discussion about this concern and work) included the children in Brooke's classroom, the two other Primary teachers, the head of school, Diana, and Brooke. Our idea for action was to create a series of shelf works designed to encourage the development of children's musical perception and cognition capabilities.

Participants

The participants were 20 children in Brooke's Primary classroom: three 3-year-olds, six 4-year-olds, eight 5-year-olds, and three 6-year-olds. Slightly more females (n = 11) than males (n = 9) were represented, the children were uniformly from middle- to upper-middle-class socioeconomic backgrounds, and all participating children were White. There were no documented learning differences among the children.

Curriculum

We designed six shelf works to encourage children to explore sound and musical concepts. Crucial to these shelf works were the design and manufacture of a device that would allow the children to quickly and easily listen to and compare various sounds. We tested several options before collaborating with one of Diana's graduate students, who had technical expertise, to design and produce the device used in this study. The device was a small, plastic box with a headphone jack, on-off switch, and battery compartment. To explore the sounds, a child placed a plastic disk on the device, and the sound immediately played through the headphones. To hear another sound, the child would replace the first disk with another. The disks were color coded to match their corresponding shelf work but were otherwise identical.

For example, all disks provided to the children for the pitch-height work matched in size, shape, and color. The only variable that changed among the disks was the sound they produced. This decision stemmed from research that indicates children will attend to changes in shape (when present) over changes in sound, color, or texture (Dansereau, 2017). Accordingly, isolating the sound variable was crucial in encouraging attention to that property.

We also designed the works to encourage children to hold sounds in working memory and to audiate. *Audiation* is a cognitive process that involves mentally replaying and comprehending sounds that are no longer present (Gordon, 2013; Runfola & Taggart, 2005); it is theorized to be necessary for achievement across a wide variety of musical behaviors (e.g., singing, playing an instrument, composing, improvising; Gordon, 2013). To complete the works accurately, children needed to correctly perceive the sounds produced by the device, comprehend the sounds after they were no longer physically present, and compare the mental representation of those sounds to other sounds.

The first work we created was designed to encourage children to explore and demonstrate their understanding of pitch height. We provided a three-dimensional wooden tree with three circular openings (Figure 1). After placing the disks on the device and hearing a pitch on each disk, the child would place the disks in the circular openings to indicate which disk produced the highest pitch, the lowest pitch, and a sound between the highest and lowest pitches.

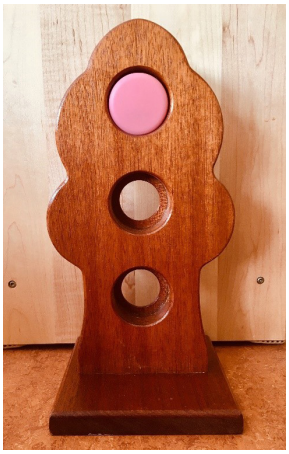

Figure 1. Three-dimensional wooden tree for pitch-height work.

This work included a control of error, which allowed the children to track their learning independently. The disks used in this study were approximately 2 inches thick, hollow, and could be opened by the children to reveal the insides of the disks. Each pink disk had a picture of the tree with the disk in the correct location inside. By opening the disk, children could check to see if their disk placement matched the picture.

The next two works centered on pitch direction. When exploring Work 2, the children heard three sliding pitches: a pitch that slid upward, one that moved downward, and a third that moved up and then down. The children demonstrated their understanding of these pitch directions by matching a two-dimensional picture to the corresponding disks (Figure 2). A colored dot inside the disk that corresponded with a dot on the back of the card served as the control of error for this work. In Work 3, the children performed the same task but used a three-dimensional manipulative to show their understanding.

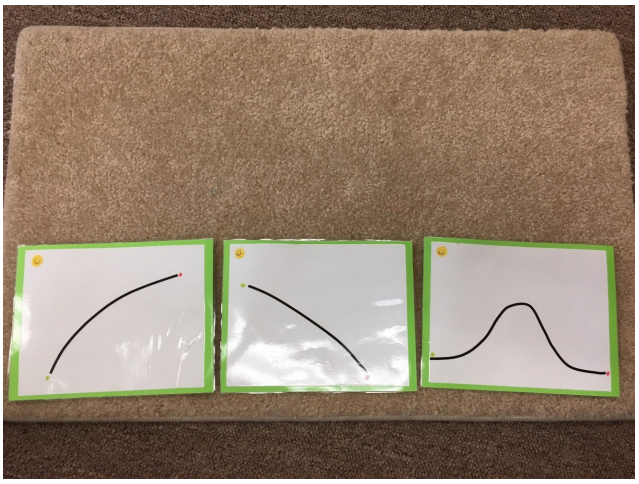

Figure 2. Two-dimensional pictures for pitch-direction work.

Works 4 and 5 were designed to apply the learning in Works 1–3 to melodic direction. In Work 4, the children heard a piece performed on piano and then moved an object (a small toy kangaroo) across a three-dimensional path to indicate the directions the melody moved (Figure 3). Completing the path before the music ended, or having the music end before the children completed the path, signaled to them that they did not follow the music accurately. In Work 5, the children performed a similar task while listening to three different melodies performed on trombone. The control of error was consistent with the control of error for Work 2.

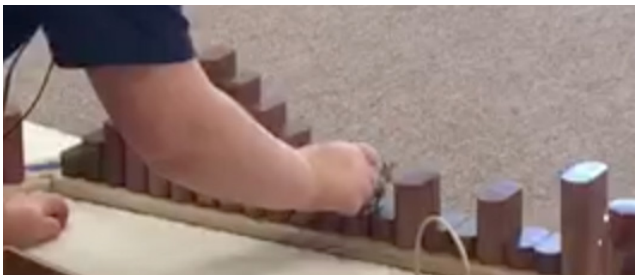

Figure 3. Three-dimensional path indicating melodic direction.

Work 6 encouraged the children to explore dynamic changes. Each disk contained a sound that increased in volume, decreased in volume, or increased and then decreased. The children manipulated a Hoberman sphere, (i.e., an orb that can expand to more than double its size and then retract), to indicate the changes they perceived (Figure 4). This work was exploratory in nature and did not include a control of error.

Figure 4. Child manipulating a Hoberman sphere while exploring dynamic changes.

Brooke introduced each work to her students during a group lesson. Consistent with the Montessori approach, she demonstrated the work in a slow and precise fashion without language. She then sat with each child while the child engaged with the work for the first time, and she documented the child's response. After each child had the opportunity to experience the work once, Brooke placed the work on the shelf to be used freely by the children during their 2-hour block of independent work. Each work was available on the shelves for several weeks.

Data Collection

As each child experienced each work for the first time, Brooke recorded descriptive data that included the child's name, age, gender, date of participation, and quantitative data related to the child's accuracy; she also recorded qualitative data in the form of notes on each child's ability to follow and replicate the procedures, perceived interest in the material, completion of the work, observed problems, and any comments made by the child. Diana completed in-class observations of the children's interactions with the materials while they were available on the shelves and recorded field notes. We maintained research journals in which we documented our thoughts about how this new curriculum was or was not meeting the goal of disrupting the perceived educational disparity described earlier.

Consistent with CPAR, we engaged in cycles of data collection, reflection, and revision. Each cycle consisted of (a) introducing the work to children, (b) collecting data on the children's interaction with it, (c) meeting to analyze the data, (d) adjusting the shelf work, and (e) determining implications for future shelf works. We repeated this process with each work we designed. In sum, we completed six of these cycles between March 2017 and March 2019.

Data Analysis

Qualitative data from Brooke's notes on the children's interactions with each work, Diana's field notes, and our research journals were coded for emergent themes by Diana and a research assistant. Themes that were present in multiple data sources were noted as patterns. We checked the themes and patterns with one another, and we triangulated the qualitative data to uncover areas of alignment and difference.

For the quantitative data, we assigned each child scores based on her/his ability to complete Works 1, 2, 3, 5, and 6[2] while being observed by Diana. If the child responded

[2] Because Work 4 did not involve sorting three different disks, it was not included in this portion of the analysis.

accurately to all three disks, the child received a score of 3. Children who responded accurately to two disks received a score of 2, to one disk a score of 1, and those who did not respond accurately received a 0. We checked these data for trends in difficulty and looked for any differences based on age or gender.

Findings

As this was a CPAR study, we analyzed and discussed evidence as part of each of the six cycles. The findings revealed during our continuous reflection informed the development and/or implementation of the subsequent work. Often, these findings pertained to components of the experience that were unexpectedly tricky for the children. For example, after introducing Work 5, Brooke wrote:

> *Children overall had less success matching these melodies correctly. My first thought was that the melodies were too difficult and needed to be longer and more dramatic. . . . I want to experiment with a couple things. First, during the group presentation I want to try listening to the melodies as a group and moving our whole bodies to correspond with the movement. . . . Another thought is to have the child match the movement in a more concrete fashion—such as moving her body, or moving a scarf.*

In addition to discussing the findings that emerged within each cycle and informed subsequent cycles, we analyzed all evidence at the completion of the study. The remainder of this section will focus on these results.

Qualitative Findings

Three primary themes emerged from Brooke's notes on the children's interactions with each work, Diana's field notes, and our research journals: positive reception, increased comfort, and fixed attention.

Positive reception

Analysis of qualitative data revealed that the works were well received by the children. Nonverbal indicators of this reception included smiles when engaged with the works, surprised expressions when hearing the sounds, persistence in engagement, and intense focus while exploring the works. Themes from the children's verbal responses included that they found the works "fun" and "cool" and that they "liked" and "loved" engaging with them. All of the children opted to use the musical shelf works initially, and some children returned multiple times while the works were on the shelves. Brooke wrote in her journal that she "found it fascinating that the children who return to the work most often are the same children who are reluctant to participate in circle time singing."

Increased comfort

Data from Brooke's research journal, as well as the documentation on the children's responses to the works, revealed that the older children appeared to become more comfortable over time as they engaged with the works. By the end of data collection, they appeared quite at ease while engaging in the listening tasks, as evidenced by their positive affect and relaxed demeanor, and all children were entirely capable of using the technological device.

Fixed attention

As data collection unfolded, we saw clear signs that children deeply fixated on the aural stimulus while engaged with the works; Brooke wrote that she had not noted this behavior in her classroom prior to the study. This fixed attention was characterized by the child ceasing all movement, staring into the distance without a specific focus, showing intense facial affect, and sometimes displaying an open mouth and/or tilted head. As Brooke noted in her research journal,

> *What I have witnessed so far with the two materials we have piloted is an overwhelming need for more of this type of work. The children in my current class have demonstrated a deeper level of concentration with this work. In part, I am sure [it is] because of the use of their auditory sense: if they are distracted by others in the classroom, listening to their friends, or carrying on a conversation, they will miss the very essence of the work. What I find fascinating is that this work must be fulfilling an essential need, because even my most social children go to the material and tune everything else out.*

Children were also observed vocalizing while they listened to the sounds or music, or afterward when explaining what they had heard to a classmate. Brooke noted that one little girl was "swooping her head as she listened to the tracks over and over," and several children used hand gestures to reflect the pitch and melodic direction.

Quantitative Findings

Analysis of quantitative data (see Table 1) revealed a perfect positive, significant ($p < .01$) correlation between scores on Works 2 and 3 (pitch-direction works), indicating that the children's response accuracy was consistent regardless of the manipulative used to demonstrate that understanding. There were no significant correlations between the scores on those two works and the scores on Works 1, 5, or 6, indicating that different processes or levels of challenge were likely involved among the tasks. There were no significant gender or age differences in the data.

Conclusions and Discussion

As articulated earlier, we noted an educational disparity in this Montessori classroom: music education was relegated to a particular time in the day and consisted of teacher-led activities within a classroom that was dominated by materials aimed at developing the visual sense. We concluded that the presence of these six curricular works began to disrupt this educational disparity. We found that the children received the works positively, chose to engage with them, became more confident in their musical tasks, showed signs of deep concentration and attention, and demonstrated consistent performance across similar tasks of perception or cognition.

Limitations

Because Brooke was busy assisting children during the independent work block, consistent tracking of children's return to the device and accuracy of response was challenging. We noted that many of the children would return to the work after their initial introduction but then return independently only one or two additional times. Some would not return despite eagerly engaging initially. We did not track the children's interactions with the works across time nor measure their accuracy across multiple attempts. Follow-up research aimed at documenting the frequency of interactions, length of engagement with the works, and comparisons with engagement in other works would be useful.

It should also be noted that the children were aware that these works were new and different from those they had experienced in earlier months or years. To collect data on every child's interactions with the works, Brooke sat with each child during his or her initial attempt, a departure from typical practice. Further, the children were aware

Table 1
Means and Standard Deviations for Shelf Works, by Age and Gender

	Music shelf work									
	1		2		3		5		6	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Age in years										
3	0.67	0.58	1.33	1.53	1.33	1.53	3.00	0	1.50	0.71
4	2.17	1.33	1.50	1.00	1.50	1.00	2.17	0.75	2.20	0.84
5	2.13	1.25	2.00	1.29	2.00	1.29	2.75	0.71	2.63	0.74
6	3.00	0	2.33	1.16	2.33	1.16	2.33	1.16	2.67	0.58
Gender										
Female	1.91	1.30	1.90	1.20	1.90	1.20	2.73	0.65	2.30	0.82
Male	2.22	1.20	1.71	1.25	1.71	1.25	2.33	0.87	2.50	0.76
Total	2.05	1.23	1.82	1.19	1.82	1.19	2.55	0.76	2.39	0.78

that their classroom was experimenting with the works but that the other classrooms in the school were not, which may have caused a novelty effect.

Discussion and Recommendations for Further Research

It became clear that the disparity we perceived may also have been seen by the children. This was likely an outcome of the *practice architectures*—the "cultural-discursive, material-economic and social-political arrangements" (Kemmis et al., 2013, p. 3) holding practices in place—that are present within the classroom, as well as the procedures that we implemented as part of our study. In future studies, the works might be introduced as equal partners with the other works in the classroom, and patterns of engagement could be tracked and compared with this study's findings. Additionally, more attention should be given to the architectures that prevent change in classroom practices and may support disparities. As Diana wrote in her research journal,

> *We are disrupting [the disparity], but not as much as we would like yet. The classroom now has another aspect of learning and engagement, but music is not balanced with the visual component of sensorial (for example). A dedicated music shelf or area, additional pairs of headphones and devices (to allow for multiple works to be used simultaneously), music works involving movement, etc. would help with this.*

In general, the tasks seemed to match the abilities of the children; only Work 4 appeared difficult, perhaps because of the quick tempo of the musical stimulus. We intend to adjust this work and then determine whether that adjustment allows it to be accessible to more children. We recommend additional research designed to understand the development of the underlying perceptual and conceptual capabilities, as well as the difficulty of the tasks.

The obvious fixed attention shown by many of the children while engaged with a work was unexpected. This level of attention may be evidence of a *flow state* (Csikszentmihalyi & Csikszentmihalyi, 1992), "an optimal state determined by an individual's perception of high skill and high challenge for a given task" (Custodero, 2005, p. 185). This state has been evident when children are engaged in a purposeful, self-initiated music activity, acknowledge error and adjust to conform to rules without adult intervention, engage in focused and controlled movement without extraneous motion, and show signs of anticipating what will come within an activity (Custodero, 2005).

Alternatively, or perhaps relatedly, the fixed attention in our study may be related to audiation. As described earlier, audiation is the mental replaying and comprehension of music when it is no longer present (Gordon, 2013). Brooke observed this when some children performed Work 4 accurately and in time, without listening to the piece of music: "I was blown away by the few children who did the work without the music. Two children vocalized the musical piece and moved the kangaroo without listening to the music!"

Audiation also can occur while listening to music and is akin to processing what another has said while engaged in a conversation (Gordon, 2013). During such a process, *audiation stare*—which is sometimes characterized by an open mouth and tilting of the head—may be observed. Audiation stare is "the first glimpse of discrimination, the realization sounds of music can be same or different" (Gordon, 2013, p. 111).

Another possibility is that the children are responding to the musical stimuli similar to how infants have been shown to respond to novel physical objects, with marked focused attention and decreased heart rate (Lansink & Richards, 1997). In this instance, music and sounds are the stimulus rather than a physically present object. More research is needed to understand the nature of this response.

The children who participated in this study were quite homogeneous in terms of race, socioeconomic status, and learning capabilities. Similar studies with more-diverse populations, as well as those that account for musical experiences occurring outside the classroom, would be highly beneficial. Additionally, studies designed to investigate potential associations between music learning in the classroom and learning within other parts of the curriculum may be informative.

This study indeed brought awareness to the uncommonness of the aural sense within this Montessori classroom and documents one approach to addressing the imbalance that was child directed, positively received,

and resulted in fixed attention to sound and music. We recommend more research and curricular innovations aimed at providing young children with a holistic education that is consistent with the child-directed principles of a Montessori education.

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Teaching in the Montessori Classroom: Investigating Variation Theory and Embodiment as a Foundation of Teachers' Development

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Keywords: *Montessori, embodiment, geometry material, mathematics, teachers' development, variation theory*

Abstract: The theory of Montessori education has been interpreted by some researchers to be vaguely formulated. However, as shown in previous research, Maria Montessori's didactic approach to teaching and learning mathematics is fully consistent with variation theory and the theory of embodiment. Dr. Montessori used the theoretical concept of *isolation of quality*, which means that the learning objects have to be kept identical except for one variable, which has to differ to be perceptible. This concept is in alignment with variation theory, which emphasizes variation as a necessary condition for learners to discern aspects of an object of learning. The other theory applied in this article is the theory of embodiment: important cognitive functions are fundamentally grounded in action that is concordant with Dr. Montessori's view that mind and movement are parts of the same entity.

This article reports on a qualitative single-case study with a formative intention in which we investigated the significance of being acquainted with variation theory and the theory of embodiment when working with Montessori material. The study analyzes a teacher's mathematics presentations with the Montessori material and the children's work with this material, using Epistemological Move Analysis, which focuses on how the teacher directs children's learning. The analysis was shared with the teacher to support her awareness of the ways teaching can be developed from a variation and embodiment theoretical perspective. Results show that the teacher's awareness of why a specific learning object must be treated in accordance with variation theory and embodiment seems to promote a more constructive and effective way to direct children's learning.

Maria Montessori described in her literature (e.g., Montessori, 1912/1964; Montessori, 1914/1965) how various didactic materials should be presented in Montessori education. However, as some interpreters of the pedagogy have pointed out (e.g., Feez, 2007; Lillard, 2005; M. M. Montessori, 1992), her description of the theory is vague. As Ahlquist and Gynther (2019) noted, Dr. Montessori gave detailed instructions on how to present the material, but she was not as explicit about the underlying didactic motives for why it should be done in the manner she described.

Cossentino (2009) stated that the focus on how Montessori material is managed in Montessori teacher training leads to the intention of Montessori pedagogy. In the present article, we take a closer look at Dr. Montessori's pedagogical intention and argue that teachers need to understand why teaching has to be facilitated and structured in accordance with the didactic intention. Such understanding is crucial in creating favorable conditions for children's learning, as well as improvement in teaching. For this to happen, teachers' lessons should be grounded in a didactic, theoretical understanding.

One key principle, which some interpreters recently have noted at a more theoretical level (e.g., Marton, 2006; Marton, 2015; Marton & Signert, 2008; Signert, 2012), is the use of variation and invariance in the training of the senses as practiced in Montessori preschools . As Marton (2015) pointed out, this training of the senses is carried out in accordance with what is emphasized in variation theory. However, Ahlquist and Gynther (2019) showed that variation theory is also valid for areas other than sensorial training. Ahlquist and Gynther showed that the use of Montessori mathematics material plays an essential role in identifying different aspects of the learning object that, according to variation theory, are crucial for a learning outcome, and the use is fully consistent with variation theory. As in Montessori education, where the use of the body is central (Montessori, 1912/1964; 1914/1965; 1948/1972; 1949/1982), Ahlquist and Gynther also stressed the importance of body-based investigations for understanding mathematical concepts. The use of variation and invariance, as well as the awareness of the theory of embodiment, can therefore be seen as a key principle in Montessori education in general, not just in sensorial training, and consequently functions as part of "a platform for teachers and others when reviewing how different topics are treated in various Montessori environments" (Ahlquist & Gynther, 2019, p. 9).

This platform was the starting point for our study, initiated in spring 2019, which analyzed a teacher's presentations in mathematics with the Montessori material and children's work with this material. The analyzed lessons were then shared with the teacher to support her awareness of the ways teaching can be developed from a variation and embodiment theoretical perspective. The aim of the study was to investigate the meaning of teachers being familiar with the underlying theories of why the material should be presented in the way Dr. Montessori described it. We established two research questions for the study:

1. What can we distinguish as an important result of the intervention between the teacher and the researchers in explicitly connecting Montessori lessons to variation theory and embodiment?
2. In what ways does the children's work change character after receiving lessons informed by variation theory and embodiment?

Montessori Education, Variation Theory, and Embodiment

In her book *Psychogeometry* (2011), Dr. Montessori considered the challenges in teaching geometry and arithmetic. She did not agree with the idea that the only thing that matters is that teachers should start with the concrete and move on to the abstract by beginning with what is easy and then, little by little, moving on to more-advanced studies. It is not just finding the most logical way to teach that will solve the problem of teaching mathematics. What is important is "that the pupil agrees to receive the knowledge and is able to pay attention or, in other words, is interested" (Montessori, 2011, p. 4). Therefore, it is essential to find the necessary conditions for "unfolding" or developing "the art of allowing joy and enthusiasm" (Montessori, 2011, p. 5). In the same chapter, Dr. Montessori broadened the challenges in teaching by discussing the concept of understanding: How can understanding become something active and not just storing a number of understood entities without any connection to interest? Here, Dr. Montessori was

very clear when she pointed out the difference between a human being and a machine. To learn something demands effort, but it is not possible to require effort when there is a lack of interest; on the other hand, when a person is interested, he or she is generally willing to put a lot of effort into the work. To become interested, a child must have the opportunity to make discoveries; at the same time, however, it is not possible to create a theorem without the proper mathematical language.

The geometry material, according to Dr. Montessori (2011), is designed to attract a child's interest in a way that teachers cannot, because the child's mind is not mature enough to receive explanations without having done his or her own explorations. The geometry material is constructed to discover the relationship between different shapes; handling the material allows the eye and mind to perceive the state of things, which enables the child to reveal what distinguishes one figure from another.

> *In other words, if we realize that there are abstract and quibbling reasonings on things that are complicated, but the things themselves, when materially observed, are much simpler, it becomes immediately evident how an alternative path can be opened up for the elementary study of geometry, leading to unforeseen results.* (Montessori, 2011, p. 56)

When viewing teaching from a variation theoretical perspective, it follows that the aim of teaching is to create conditions that will help the learner perceive the necessary aspects of the object of learning and the relationships between them. Learning, according to Marton and Booth (1997) and Marton (2015), is when the learner has learned some aspects that he or she was not aware of before. Variation theory, therefore, as well as Montessori education, stress that the relationship between what can be seen as the whole and its parts must be perceived by the learner if learning is to take place. Lo (2012) argued:

> *There must be a whole to which the parts belong before the parts can make sense to us. We cannot learn more details without knowing what they are details of. When the whole does not exist, learning will not be successful.* (p. 26)

Dr. Montessori made the same point: "To teach details is to bring confusion; to establish the relationship between things is to bring knowledge" (Montessori, 1948/1996, p. 58).

From a variation theoretical perspective, a learner has to be aware of the differences between at least two features to be able to discern them (Marton, 2015). For example, to discern the shape of a triangle, the learner has to be exposed not only to a triangle but also to other shapes (e.g., a square). In that way, learners will be able to discern a triangular shape at the same time that they discern what is not triangular. However, other aspects, like color and size, have to be kept invariant to make it likely that the learner discerns the aspect in focus (i.e., shape). As Dr. Montessori (1948/1972) wrote, "If, for example, we want to prepare objects to be used in distinguishing colors, we must make them of the same material, size, and dimensions, but then see that they are of different colors" (p. 101). Once learners have found the meaning by contrast, they have to generalize the aspect that had previously been separated. If the aspect, for instance, is shape, generalization is achieved by keeping the shape invariant and varying other aspects, such as color and size. From a variation theoretical perspective, it is important that such a generalization always be preceded by contrast (Marton, 2015). The final step is to let learners experience simultaneous variation in all relevant aspects. In variation theory, this pattern of variation is called *fusion*: "it defines the relation between two (or more) aspects by means of their simultaneous variation" (Marton, 2015, p. 51). In the case of a triangle, learners will experience, for instance, that any triangle that appears—whatever its size, color, length of sides, or different kinds of angles—is still a triangle.

Furthermore, learning, according to Dr. Montessori (1948/1972; 1949/1982), manifests itself through experiences in the environment; consequently, she considered bodily actions to be central in shaping our experiences and perceptions of the world around us. This view of learning is in accordance with the theory of embodiment, which sees meaning and cognition as deeply rooted in our physical existence. The embodied mind is not only an organ situated inside our body; according to Lakoff and Johnson (1999), it is also our bodily experience and interaction that supports our systems

of thought. Embodiment is considered to be action and perception, grounded in the physical environment.

> *Meaning is embodied. It arises through embodied organism-environment interactions in which significant patterns are marked within the flow of experience. Meaning emerges as we engage the pervasive qualities of situations and note distinctions that make sense of our experience and carry it forward. The meaning of something is its connections to past, present, and future experiences, actual or possible.* (Johnson, 2007, p. 273)

Dr. Montessori (1949/1982) wrote that the hand explores and communicates with the brain at the same time the brain guides the hand. According to Dr. Montessori (1949/1982) this similarity supports the learning outcome since it is through these explorations that the mind not only has the power to imagine but can also assemble and reorganize its mental content. The similarity between the hand and the brain is consistent with Merleau-Ponty (2004), who stated that movement must be understood as an original intentionality and that consciousness does not mean "I think" but rather "I can" (p. 159). The use of Montessori material can be seen as an expression of this crucial standpoint.

Method

This study is a qualitative, single-case study that includes a formative intervention. *Formative intervention* means that analysis of the collected data and how the teaching can be developed from a variation theoretical perspective and awareness of embodiment were shared and discussed with the teacher throughout the study. The design of the study promoted active participation by both the researchers and the teacher regarding the implementation of the actions that occurred. The intention was to enrich the teacher's own learning of how to give presentations and prepare activities in mathematics.

The data were collected in field notes from several observations in a mixed-age Montessori class in a large city in Sweden, with 7- and 8-year-old children in their first and second school year. Before the study, a letter describing the study, including a guarantee that the school's location and the children's names would be anonymized, was sent to the parents with a form to be detached, signed, and returned to the principal; all parents gave their approval. The teacher informed the children about the study, and all children could choose not to participate in the study and to instead work with their classmates in another classroom; however, none chose this option. According to Stockholm University's Research Support Office, the study did not require approval from the Swedish Ethical Review Authority.

The subject teacher had received Montessori training from a Swedish university, was a licensed elementary teacher, and was chosen because of her specialized background in mathematics. We followed the teacher's presentations in mathematics through five sessions and observed the children's learning during a period of 3 weeks. The study includes sections in which the researcher interacted with the children during their activities to identify their learning ability and understanding. The researchers' observations focused on what the teacher or researcher said to the children and how the material was managed. Actions and expressions unrelated to the content being treated were disregarded. During the observed lessons and activities, the researchers took brief notes related to the focus of the study. Later that day, they added to these notes and developed them into more complete and detailed descriptions. To give a clear, explicit picture of the observations, and in alignment with Yin's (1994) recommendations, we decided to include long descriptions of the observed activities in the reported findings. For better access to classroom events, we decided not to use video or audio recording during observations. Both researchers were in the classroom at the same time, which helped reduce subjective understanding and increase the reliability of the data collected.

The teacher's role in the children's learning process, as well as the researchers' role as participants, was analyzed with the aid of Epistemological Move Analysis (EMA), which analyzes a teacher's role in students' learning process. (Lidar, Lundqvist, & Östman, 2006; Lundqvist, Almqvist, & Östman, 2012). In our analysis, we focused on how the teacher directed the children's learning in different ways by using what Lidar et al. (2006) referred to as *epistemological moves*, which we found suitable for the study. These different moves were (a) *instructional moves,* which instruct children and direct them how to act so they can see what is worth noticing (in our study, this

meant how to use the Montessori material to comprehend and define the desired learning outcomes); (b) *confirming moves*, when teachers agree with (i.e., confirm) what children say or do by, for instance, giving positive feedback; (c) *reconstructing moves,* which are used when children pay attention to what they have noticed but have not yet comprehended, giving them the opportunity to reflect on their experiences in the work with the material; (d) *reorienting moves,* which encourage and challenge children to try out another way to deal with the task; and (e) *generative moves,* which enable children to generate understanding by reporting on the important knowledge they have perceived in the activity.

The collected data also included two interviews with the teacher in which we discussed the lessons and interactions with pupils. At the teacher's request, these interviews took place at Stockholm University and were recorded and later transcribed. The interviews were open-ended and semistructured; no interview guide was used, but the use of target questions provided insight into the teacher's thoughts about her teaching. After the interviews were transcribed, we followed up with the teacher for clarification and further details, covering several issues: the aim of the presentations; how the teacher planned to make complex concepts intelligible to the children; how she had planned the follow-up activities in mathematics for the children; and the roles of the teacher and researchers as participants in the children's learning process, as analyzed with the aid of EMA.

We also asked the teacher to reflect on how many children she chose for the presentation and how the environment was set to prepare for the activities in mathematics. The teacher gave her opinion on the lessons: what was successful and what she could have done in a different way. The discussion included our observations of the teacher's presentation and what we noticed during our interaction with the children, for example, how the children interpreted the activity, how they managed to complete the exercises, and what we noticed about their learning outcome. Discussing these sessions and learning activities with the teacher created conditions for development of the presentations. Together with the teacher, we agreed on ways to develop presentations and to set up new learning activities in which variation theory and the theory of embodiment were more evident. We maintained this work model throughout the study, so we were able to test how the children responded to the enhanced designs of the presentations.

Findings

In this section, we present patterns we identified while observing the teacher's presentations and the children's individual work. To illustrate how these patterns appear in the activities, long descriptions of observations, presented as narratives, are included.

Teachers' Presentations

In our initial observations of the teacher's presentations, we noticed that the feature they shared was that the children who participated in them mostly received information from the teacher (i.e., instructional moves), rather than opportunities to express how, or to what extent, they understood the content. Thus, in the first observed presentation, no reconstructing, reorienting, or generative moves were used by the teacher.

For example, in one instance the teacher had gathered 14 children for a presentation of polygons. The children sat on a circle-shaped carpet. A drawer[1] containing polygons was placed in front of the children, and the teacher began the presentation by saying, "Today, I am going to present polygons. *Poly* means *many* and *gon* means *corner*. What then does *polygon* mean?" One of the children quickly answered, "Many corners," which the teacher confirmed with a nod. The teacher then placed beside the drawer cards with the numbers 5, 6, 7, 8, 9, and 10. Next, the teacher picked up the pentagon and slowly, with a circular movement, felt along all the sides of the pentagon with her index and middle fingers as she counted the corners of the pentagon. Then she said, "*Gon* means *corner* and *five* in Greek is *pente*. So, what do you think is the name of this polygon?" One of the children immediately answered, "Pentagon." The teacher then presented the hexagon, heptagon, octagon, enneagon, and decagon in the same way. At the end of the presentation, the teacher told the children to feel the sides of each polygon with their index and middle fingers and then draw the polygons in their geometry books, writing the name of each polygon they had drawn.

[1] The drawer used in the presentation is part of the Geometric Cabinet, which was described in a previous study by Ahlquist and Gynther (2019).

At the end of the day of the presentation, we sat with the teacher and shared our reflections about what we had observed. The teacher told us, among other things, that she was not satisfied with the presentation of the polygons because she had not succeeded in engaging the children. According to the teacher, this result was also because the number of children present was quite large, making it even more challenging to engage all of them. As a result, we began to discuss what, in Montessori education, is a suitable number of children for a presentation like this; in our experience, Montessori teachers frequently discuss this issue. Dr. Montessori's own writings (e.g., Montessori, 1912/1964) referred to dialogues and discussions with groups of children, and we can assume the groups were of a manageable size. If dialogue and discussion are to take place and children are to have the time to explore, touch, and trace the material, there must not be too many children. A well-balanced number of children allows the teacher to follow each child's understanding of the material and its mathematical content. The meaning of a well-balanced number of children was shown by Blatchford (2003), who stated that "there is a strong suggestion that in a small class a teacher will more easily be able to provide at least some aspects of effective scaffolding for her pupils" (p. 590). The groups should not be too small either, as children are successful when they help each other by reasoning and explaining their own understanding (Wiliam, 2019).

We therefore agreed that in the next session we observed, the teacher should try to make a similar presentation to fewer children, letting them describe in more detail the similarities and differences between the geometrical shapes. We assumed that the children's knowledge would then be apparent to the teacher, thereby creating conditions for the teacher to direct the children's learning during the presentation with other epistemological moves besides instructional ones. At the same time, according to variation theory, the different shapes would be contrasted with others, making the aspect that defines each shape clearer for the children. We also discussed the probable critical concept for distinguishing different polygons: the corners of the shapes. However, when reviewing how the different polygons were presented, we all questioned whether it was wise for the teacher to trace the sides of the pentagon with her index and middle fingers while counting the corners. The teacher said this was what she had been taught to do in her Montessori training. We asked her if that might not confuse the children, as the teacher was supposed to count the corners and not the sides. After reflection, she agreed and said she wanted to change how she presented polygons the next time. We also encouraged her to reflect on the critical aspects of the learning object in the presentation to come and how to better engage the children.

In the next session, we observed her present quadrilaterals to the children. This time only five children were invited to participate, and a drawer[2] containing various quadrilaterals was placed in front of them. Before she directed children's attention toward the drawer, the teacher showed them the equilateral triangle she held in her hand. As it is not important to distinguish each individual child in this presentation, we refer to them as *child* in the following section.

Teacher: "What can you tell me about this triangle?"
Child: "It has three corners and three sides."
Child: "It is equilateral."
Teacher: "Yes, what does that mean?"
Child: "It has equally long sides."
Teacher: "How about the angles?"

One of the children took the triangle and checked whether the corners of the triangle would fit in one of the corners of the box.

Child: "They are acute."
Teacher, now showing the children a quadrilateral: "What can you tell me about this one? What is the difference between this one and the triangle?"
Child: "It has four corners."
Teacher: "How about the sides? Are there any parallel sides? You can check it out with these two rulers."

One of the children put rulers along two opposite sides of the quadrilateral.

Child: "No!"
Teacher: "How about the other two sides?"

[2] This time, the teacher had prepared a drawer with various quadrilaterals (quadrilateral, trapezium, parallelogram, rectangle, rhombus, and square) that had been taken from the second and fourth drawers in the Geometric Cabinet. For a description of the cabinet, see Ahlquist and Gynther (2019).

The child checked these sides and stated that they were not parallel either.

> Teacher: "What does parallel mean?"
> Child, illustrating this with the two rulers: "It is sort of like they don't go together."
> Teacher, pointing at the direction of the rulers: "Yes, they never meet each other even if they continue as far as we can see."
> Teacher, taking a card and reading the text on it: "It has four corners and four sides. Two sides are parallel. Which one of these [points at tray] could it be?"

The children looked at the tray, and one of them suggested the parallelogram.

> Teacher: "Does it have two parallel sides?"
> Child, checking with the rulers: "Yes!"
> Teacher: "How about these two sides then?"

The child checked them and stated that they were parallel as well.

> Teacher: "So, does it have two parallel sides?"

The children seemed to understand it was not the right one and then suggested the trapezoid, which they investigated with the rulers. The teacher then continued to read other cards for the children; finally, they had investigated all of the shapes and laid them on the carpet: quadrangle, trapezoid, parallelogram, rectangle, rhombus, and square.

> Teacher: "Now look—what is the difference between this one [indicating the quadrangle] and this one [indicating the trapezoid]?"
> Child, pointing at trapezoid: "This one has parallel sides, but this one [indicating the quadrilateral] doesn't."
> Teacher: "Exactly."

The teacher continued presenting the rectangle and square and then asked the children to describe the differences between the trapezoid and parallelogram, between the parallelogram and rectangle, and so on. Finally, the teacher asked the children to draw the quadrilaterals and write the names in their geometry books.

When looking back at the presentation described above, we noticed that the way the teacher gave her presentation differed from the way she had done it previously. This time, she began the presentation with a generative move by asking the children to describe the sides and angles of the triangle she held in her hand. In doing so, she enabled them to summarize what they had perceived in previous work with different kinds of triangles; consequently, in this case, the teacher was now aware whether the children understood what defined a right angle. This understanding was crucial when, for example, she later asked the children to describe what distinguishes a rhombus from a square.

Another example of a generative move was asking the children to explain the meaning of *parallel*, another critical aspect of identifying different quadrilaterals. It is reasonable that such generative moves, which were absent in the presentation described earlier, were used now because the teacher had reflected more on critical aspects.

In this presentation, the teacher also used contrast more, for example, by asking the children to investigate different shapes and describe their differences. Exposure to one specific quadrilateral lets children differentiate between the aspects that define the shape and those that do not. Other aspects, like color, remain invariant by the design of the material; therefore, according to variation theory, it is likely that the children will discern the aspect in focus.

The above illustration also creates conditions for the teacher to identify children's knowledge. In that way she will, during this presentation, direct their learning by using not only instructional moves but also confirming, reconstructing, and reorienting moves. In the presentation, the teacher confirmed the children's answers or actions either by statements or by moving on in the presentation. An example of a reconstructive move was the teacher asking the children to pay attention not only to the sides but also to the angles of an equilateral triangle. Finally, the teacher used a reorienting move when she had the children pay attention not only to the number of sides in a trapezoid but also to their relation to each other, another critical aspect of identifying and distinguishing different quadrilaterals.

However, awareness of critical aspects of the content is not the only necessary condition for successfully directing

children's learning. Such directing must also be grounded in an awareness of the relationship between the children's knowledge and the intended learning object. According to the two presentations described, contrasting different shapes in a dialogue with the children created conditions for them to discern the different shapes and for the teacher to acknowledge the relationship between the intended learning object and what the children actually learned.

On the other hand, it is important to note that the task the children were supposed to work on independently (i.e., draw the shape and write its name) did not create those conditions. If the children had been asked not only to draw and write the names of the different quadrilaterals but also to describe what distinguishes each of them, it would likely have been easier for the teacher to identify whether each child needed to continue working to reach the intended learning object and if so, with what. Even if the children's individual work in this case did not create conditions for the teacher to identify critical aspects of the learning object each child had grasped, such conditions were created in other cases. For instance this was noticeable when some of the children in one of the sessions worked with a game using geometric solids, described next.

The Children's Individual Work With the Owl Game

During this observation, two boys were engaged in a game devised by Littler and Jirotková (2004), called the owl game, in which one boy asks yes–no questions of the other boy to find out what kind of solid the other boy had hidden under a cloth. The teacher had previously presented the solids, after which the boys performed a task in which they had to place the names of the solids under pictures of them.

When the game started, several shapes (i.e., a square pyramid, a triangular pyramid, a cube, a triangular prism, a rectangular prism, a sphere, an ovoid, an ellipsoid, a cone, a cylinder) were under a cloth. One of the boys, David, held a solid under the cloth without showing it to his classmate, Jonathan (both names are pseudonyms). Jonathan started asking questions to find out which solid David was holding in his hands. The researcher sat beside them, observing, and was able to intervene during their work. During the first section of the game, Jonathan had trouble imagining the hidden solid.

Jonathan: "Is there a sharp edge?"
David: "Yes."
Jonathan: "Are there sides?"
David: "Yes."
Jonathan: "Is it a pyramid?"
David: "No."
Jonathan: "Is it a cube?"
David: "No."
Jonathan: "Is it a triangular prism?"
David: "No."

David then showed Jonathan what he had been holding in his hand, a rectangular prism. Then Jonathan hid his hands under the cloth and held a solid. David asked if the solid had four sides, and Jonathan answered that it did not. David then asked if it had angles. When Jonathan affirmed it did, David asked if the angles were all equal. Jonathan reflected and said he did not think they were equal. David then started guessing.

David: "Is it a square pyramid?"
Jonathan: "No."
David: "Is it a cube?"
Jonathan: "No."
David: "Is it, well, I don't know, maybe a cone?"
Jonathan: "Yes."

The researcher, who had been watching the boys, asked them to remove the cloth.

Researcher: "Can we have a look at the solids again?"

After the boys agreed, the researcher asked them to identify the solids with flat surfaces and the solids with curved ones. She told the boys to touch the different surfaces of the solids, identifying flat and curved ones. They touched the surfaces in the same way the researcher did, moving their fingers slowly along the different surfaces and explaining their experiences.

When they seemed to grasp the concept, the researcher asked them to place the solids into two groups according to whether they had flat or curved surfaces. Two solids remained, the cone and the cylinder. The researcher asked why they had not placed them in one of the two groups, and the boys replied that those solids were both flat and curved and should be placed in a third group. She then took the two solids from the group with flat surfaces (i.e.,

the square pyramid and the triangle pyramid), put them on their bases, picked up the square pyramid, and pointed at its base. She turned to Jonathan and asked him to identify the shape of the base. He answered that it was a square. She handed him the pyramid and asked how many sides the solid had. He immediately answered that it had four sides. The researcher asked him to look carefully and count them. He turned the solid around, recognized his mistake, and replied quickly without counting the sides: "Five," he said. She then turned to David and asked him how many triangles there were. He answered that there were four. "How do you know without counting them?" asked the researcher. "Because the base is a square," David replied. The researcher then asked him if he knew what the triangles were called. He shrugged his shoulders. Slowly the researcher marked the sides with her fingers and then moved the triangle in a walking motion (In Swedish, an isosceles triangle is *likbent*, meaning *with equally long legs*.) David smiled and said, "Oh, yes, it`s an isosceles triangle." Then the researcher picked out the triangular pyramid, pointed at its base, and handed it to Jonathan; she let the boys identify it in the same way they had with the square pyramid. This identification process went well and quickly.

Next, the researcher told the boys to ask as few questions as possible about one of the two pyramids, picking out the one with a triangular base. She put it in front of the other solids.

> Researcher: "Let's look at the surfaces. What is the first question you'd ask, David?"
> David: "Is the surface only flat?"
> Researcher: "Okay. What information would you get? Which of the solids can you skip?"
> David: "The ones with curved surfaces."

The researcher took away the solids with curved surfaces and placed the other solids with the pyramids.

> Researcher: "Now, what question could we ask here, Jonathan?"
> Jonathan: "Does it have a rectangular shape?"
> David: "No!"
> Researcher: "That's a good question—so, which of the solids can we take away?"

The boys took away the solids with rectangular shapes.

> Researcher: "Okay, now, here we have three solids. How can we make sure that we ask a question about the triangular pyramid?"
> David: "Are there only triangular shapes?"
> Researcher: "Okay. Jonathan, will you take away those that do not have only triangular shapes? You see, now there is only one solid that matches the question."

The two boys remained engaged and wanted to continue the game. The researcher asked them to identify the other solids before playing the game again. When they did, it appeared they were not sure of all the names of the shapes. The researcher asked them to look at their notebooks, where they had drawn the shapes and written the names, and encouraged them to make additional notes. Jonathan looked at his notes and asked what he should write. The researcher pointed at his drawing of a rectangle and asked him about the shape.

> Jonathan: "It's a rectangle."

The researcher asked him to define a rectangle. He answered correctly, and the researcher asked him to add the description to his notebook.

In the activity with solids, the two boys seemed able to visualize the solids because they grasped them and touched the surfaces with their hands. Grasping is crucial when teaching and learning geometry, according to Mwingirwa, Marguerite, and Khatete (2015), because many students lack spatial ability. The teacher therefore cannot expect that "his/her students are able to visualize figures, shapes and planes that may not be very obvious to the student" (p. 19).

When learning is seen as embodied, the material used in the owl game creates conditions that make it possible to connect the mind with the body, consequently, as Scoppola expressed in his preface to *Psychogeometry* (Montessori, 2011), ". . . making children 'perceive' deep relationships in order to 'prepare' the mind for the systematic study of the discipline . . . " (p. xvii). At the same time, it became clear in the activity that the material itself did not create such conditions unless the two boys had access to concepts necessary for this to happen. The

task the boys had completed before the owl game (i.e., placing the names of the solids under a picture) did not seem to help much in regard to a systematic study of the solids and the relationships between them. A picture of a three-dimensional figure was problematic, as the boys seemed to lack a more profound, body-based experience. For example, when David asked questions and was supposed to conclude that Jonathan held a cone in his hand, he needed to be familiar with what constitutes flat and curved surfaces, concepts that he did not yet seem to understand as a feature that distinguishes the solids.

Analysis of the boys' work clearly shows they needed support. The goal of the owl game was to distinguish the solids, but simply being shown the material and then working with the pictures and labels did not help the boys succeed. To succeed in the owl game, they needed more body-based experience and guidance to distinguish certain critical aspects, which the researcher created by contrasting one solid with another. This reconstructing move showed a need for intervention, as it very soon became clear that the boys did not know how to distinguish the different solids. The researcher initially gave them some instructions, but then her epistemological moves were of a reconstructional nature, for instance, when she asked them to touch the different surfaces. Now they could distinguish the concept of *surface* and could place the solids in different categories according to their surfaces. The researcher confirmed their work by letting them move on as soon as she saw they knew what they were doing. There were also times when the researcher used reorienting moves, for instance, when Jonathan said that the square-based pyramid had four sides and he had the opportunity to reexamine the solid in question, thereby generating an explanation.

When we discussed this episode with the teacher, she realized that the children needed both more practice in identifying the different shapes and more time to understand certain concepts and characteristics through isolating, sorting, and classifying, activities they had not been able to do previously. At this point, it became obvious to the teacher that the Montessori material was essential, not only to establish concepts but also for the children to become aware of the shapes by bodily experiencing them. According to variation theory, it is essential in this work that the teacher organize the solids according to contrast, to make it possible for the children to discern the aspects in question. A first exercise, therefore, could be to let the children sort the solids using everyday objects, such as a ball for solids with surfaces without borders; a soup can, which has surfaces with and without borders; and a box, where all the surfaces have borders.

Discussion

In the previous sections, we showed how the intervention between the teacher and the researchers—for example, discussing what should be seen as critical in the content she was covering and the relation between such aspects and the observed teaching—seemed to have increased her awareness of the content-related aspects that she needed to address and clarify in her teaching and how she will do that. It also made her more aware of the relation between the children's actual knowledge and what they were supposed to learn. In variation theory, paying attention to what was conceptualized as the intended (i.e., planned), enacted (i.e., offered) and lived (i.e., discerned) learning object created conditions for the development of her teaching. For example, after we talked with the teacher about the owl game, she decided to present the blue solids differently next time. She would have the children pay attention to the names of the solids and their side surfaces, and she would let them hold the solids in their hands and focus on how different solids contrast with each other, giving them opportunities to make discoveries and arouse their interest. For instance, the children would contrast solids that had only curved surfaces with those that had only flat surfaces, as this was a critical aspect of the learning object for which they lacked the necessary concepts. In this way, according to variation theory and embodiment, the teacher would manage the intended learning object in a more powerful way.

As stated above, a prerequisite for such improvement is that the lived learning object become visible for the teacher. By reducing the number of children in the presentations and letting them play a more active role—letting each child, for example, describe the differences and similarities between geometrical shapes—it was possible for the teacher to identify how the children perceived the phenomenon. Such changes in the way the presentations were organized and conducted obviously not only gave the children an opportunity to adopt a more resonating and reflective attitude, but, by using different

epistemological moves, it also allowed the teacher to direct the children's learning in a different way than before. However, these changes also presented challenges for the teacher in regard to the children who did not participate in the presentation. The teacher expressed this in one of the interviews:

> *I have to give presentations on more than one occasion about the same thing, and I feel that the presentations are carried out in a better way now. But that means I have less time to move around in the classroom and support the children in their work.*

In other words, when the number of children in the presentations was reduced, she needed to give the same presentation several times, which made it more challenging for her to support the children when they worked independently. This organizational change created a dilemma for her, which in itself indicated that the amount of support given in a more formal way (e.g., gathering all the children and following up on the lessons or giving written comments) was low. This low level of support was also confirmed in our observations. However, solving this dilemma with formal support presupposes that the tasks the children work on independently and then document in their workbooks are designed to make the relation between their knowledge and the intended learning object visible to the teacher. Such conditions were not created when the children worked independently with the different quadrilaterals. They only drew the shapes and wrote the names in their geometry books, which did not create conditions for the teacher to notice whether the children knew what defined each shape. If, instead, the children had written what they had discovered, their reasoning would have been visible, allowing the teacher to see how they perceived the learning object.

Whether the need for support is resolved formally or informally, the results of this study indicate that teaching needs to be designed so that teachers can better direct children's learning by using different epistemological moves, as shown in the owl game. However, as Lidar et al. (2006) mentioned, it is not enough to use the right epistemological move with a child. As in the owl game, there also has to be "a change in the students' practical epistemology, their learning of how and what to observe, [which] is a way of getting closer to the scientific concept" (Lidar et al., p. 13). According to Lithner (2015), rote learning and procedures will not solve learning difficulties in mathematics. For example, to analyze geometrical figures, children need concepts to describe them, such as angles, length, parallel sides, and so on. Knowing to describe a square as having four equally long sides and four right angles, for instance, makes it possible for children to precisely explain their knowledge of the figure.

> *Underlying most geometric thought is spatial reasoning, which is the ability to "see," inspect, and reflect on spatial objects, images, relationships, and transformations. Spatial reasoning includes generating images, inspecting images to answer questions about them, transforming and operating on images, and maintaining images in the service of other mental operations.* (Battista, 2007, p. 843)

Directions and practice in different learning situations will give children several learning opportunities. However, in the work to make the knowledge their own—in this case, to learn about geometric shapes and solids—it is essential that children be able to see critical aspects of a subject, to distinguish, for example, one solid from another and to grasp what characterizes each solid. As the results of this study show, this teacher's awareness of why a specific object of learning was to be treated in accordance with variation theory and embodiment seemed to help her successfully use epistemological moves in a more encouraging and constructive way.

Although this study is limited to one teacher and therefore cannot be generalized, it emphasizes the need for teachers to be aware of the motives underlying the ways their teaching is implemented if the conditions necessary for improvement are to be created. As the interventions between teacher and researchers in this study show, insights into variation theory and embodiment may help Montessori teachers deepen their awareness of such didactic motives.

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