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From the editor:

I am pleased to present the second issue of the *Journal of Montessori Research*. The positive feedback from the first issue and the continued interest in the publication demonstrate the importance of the journal's contributions to the Montessori community and the broader field of education.

This issue includes articles on empirical studies from two prolific lead authors with a history of exceptional publications in the field of psychology. Angeline Lillard, along with coauthor Megan Heise, continues her line of inquiry into the importance of Montessori materials in outcomes for Primary children. Elida Laski and her colleagues make an important contribution to our understanding of mathematical thinking in Montessori children. A third article uses student-voice theory to explore self-determination in a Montessori adolescent program providing the student perspective in the discourse on middle-school reform.

Important opportunities can come from the existence of a peer-reviewed, scholarly journal dedicated to Montessori education. The first of these was the inclusion of a Journal Talk about publishing in the *Journal of Montessori Research* at the American Educational Research Association (AERA) Annual Meeting in Washington, DC, in April. In addition, efforts are under way to establish a Montessori education Special Interest Group (SIG) within AERA. If you would like more information about how to support this effort, please contact the editor.

I would like to thank all the individuals who contributed to this issue and recognize the support of the American Montessori Society (AMS) and the University of Kansas Libraries in making this publication possible. In addition to the three articles in this issue, we have several more in various stages of review, so look for another issue in November of 2016.

Sincerely,

Angela K. Murray, PhD
Editor
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Longitudinal Comparison of Place-Value and Arithmetic Knowledge in Montessori and Non-Montessori Students

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Keywords: *arithmetic, base 10, place value, Montessori, early childhood mathematics*

Abstract. Understanding of base 10 and place value are important foundational math concepts that are associated with higher use of decomposition strategies and higher accuracy on addition problems (Laski, Ermakova, & Vasilyeva, 2014; Fuson, 1990; Fuson & Briars, 1990; National Research Council, 2001). The current study examined base-10 knowledge, place value, and arithmetic accuracy and strategy use among children in early elementary school from Montessori and non-Montessori schools. Children ($N = 150$) were initially tested in either kindergarten or first grade. We followed up with a subgroup of the sample ($n = 53$) two years later, when the children were in second and third grades. Although Montessori curriculum puts a large emphasis on the base-10 structure of number, we found that children from Montessori schools showed an advantage on correct use of base-10 canonical representation in kindergarten but not in first grade. Moreover, no program differences were seen in place-value understanding in second and third grades. Although Montessori children used different strategies to obtain answers to addition problems in second and third grades as compared with non-Montessori children, no program differences in addition accuracy were found at any grade level. Educational implications are discussed.

Mediocre mathematics achievement has been a persistent problem of the United States' educational system. On international comparisons of mathematical knowledge, the performance of U.S. students perennially lags behind that of same-aged peers in East Asia and much of Europe (Gonzales et al., 2009). Results of national assessments within the U.S. are no more encouraging; on the most recent National Assessment of Educational Progress, 26% of U.S. eighth graders performed at a level classified as *below basic* (National Center for Educational Statistics, 2013). These inadequate levels of mathematics achievement negatively affect both the national economy and individual college, career, and economic opportunities (National Mathematics Advisory Panel, 2008).

Ensuring that children acquire basic numerical understanding in early childhood is central to improving mathematics achievement in the United States. Early mathematical knowledge predicts rate of growth in mathematics (Aunola, Leskinen, Lerkkanen, & Nurmi, 2004) as well as mathematics achievement test scores as late as high school (Duncan et al., 2007; Jordan, Kaplan, Ramineni, & Locuniak, 2009; Stevenson & Newman, 1986). Specifically, place-value and arithmetic knowledge are foundational for later mathematics learning (Kilpatrick, 2001; Mix, Prather, Smith, & Stockton, 2014). The present study examined whether the Montessori approach promotes a better understanding than other public-school approaches of three foundational aspects for later mathematics learning: (a) base-10 and place-value understanding, (b) ability to accurately solve arithmetic problems, and (c) use of base-10 decomposition, an efficient arithmetic strategy.

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Literature Review

Base-10 and Place-Value Understanding

A multitude of studies have found that place value is a difficult concept for young children (Carpenter, Franke, Jacobs, Fennema, & Empson, 1998; Cauley, 1988; Cobb & Wheatley, 1988; Fuson, 1986, 1988, 1992; Fuson & Briars, 1990; Ginsburg, 1989; Kamii, 1986; Miura & Okamoto, 1989; Resnick & Omanson, 1987; Ross, 1989, 1990; Varelas & Becker, 1997). It takes several years for children to develop an understanding of the base-10 system and place-value notation. Preschool-aged children are able to judge relative magnitude of multidigit numbers and map large number words onto written symbols. However, before formal schooling, most children think of numbers larger than ten as collections of units rather than as groups of tens and units (Mix et al., 2014). Children's understanding of the base-10 numeric structure is typically assessed with a block task (e.g., Miura, Okamoto, Kim, Steere, & Fayol, 1993), in which children are asked to represent two-digit numbers using a combination of unit cubes and ten-bars. Between kindergarten and second grade, children increasingly use both tens and units to represent two-digit numbers (Miura et al., 1993; Saxton & Towse, 1998). Thinking of multidigit numbers as groups of tens and units translates into later place-value knowledge, which is critical for more complex arithmetic operations (e.g., 27 + 14). Varelas and Becker (1997) found that the percentage of children who both traded correctly and correctly identified digits in the tens place on a written arithmetic task increased from 56% to 77% to 98% between second and fourth grades. Comprehension of base-10 structure suggests a deeper understanding of how numbers relate to each other and how numbers can be incremented by intervals greater than one, such as tens and hundreds. Both of these skills are useful when manipulating numbers. Kindergartners, for example, who represent double-digit numbers as a collection of tens and ones rather than as individual units, are more likely to use sophisticated addition strategies such as decomposition, which in turn is related to greater accuracy in arithmetic (Laski et al., 2014). In later elementary school, base-10 knowledge is related to accuracy on multidigit arithmetic problems (Fuson, 1990; Fuson & Briars, 1990; National Research Council, 2001).

The age at which children accurately use 10 blocks and unit blocks to represent two-digit numerals seems to depend, in part, on their instructional experiences (Fuson & Briars, 1990; Fuson, Smith, & Lo Cicero, 1997; Hiebert & Wearne, 1992; Miura et al., 1993; Varelas & Becker, 1997). For example, Saxton and Towse (1998) found that a practice trial in which the experimenter demonstrated how to use 10 blocks and unit blocks to represent double-digit numbers had a substantial positive effect on the extent to which young children used both 10 blocks and unit blocks to represent double-digit numbers. Further, a recent study found no differences between East Asian and American kindergartners' use of base-10 representations in children with less than one year of formal instruction (Vasilyeva et al., 2015), despite these differences being well documented at the end of first grade, after more than one year of formal instruction (e.g., Miura et al., 1993). The Montessori mathematics curriculum places great emphasis on base 10 and place value using a series of materials (e.g., golden beads, stamp game, bead frames) that highlight these concepts, even with children as young as 3 years (Laski, Jor'dan, Daoust, & Murray, 2015; Lillard, 2005; Montessori & Simmonds, 1917). Thus, it seemed plausible that differences in young children's understanding of base 10 and place value may exist based on whether they had experienced Montessori mathematics instruction between the ages of 3 and 6 years.

Arithmetic Accuracy and Decomposition Strategy

To be successful in more complex math problem solving, children must first learn to accurately and efficiently solve simple arithmetic problems in early elementary school (Cowan et al., 2011; Jordan, Kaplan, Oláh, & Locuniak, 2006). Children can arrive at solutions to addition problems through various strategies, each of which includes certain prerequisite skills. When asked to solve problems without paper and pencil, children typically use one of three types of addition strategies: (a) counting, (b) retrieval, and (c) decomposition (Geary, Bow-Thomas, Liu, & Siegler, 1996; Geary, Fan, & Bow-Thomas, 1992; Shrager &

Siegler, 1998). Counting involves enumerating both of the addends or counting up from one of the addends. Retrieval involves recalling the solution to a problem as a number fact stored in memory, rather than active computation. Decomposition involves transforming the original problem into two or more simpler problems, which often involves first solving for ten (e.g., base-10 decomposition: solving 6 + 5 by adding 6 and 4 to get to 10 and then adding 1 more).

The base-10 decomposition strategy is one of the most efficient mental strategies for accurately solving arithmetic problems, particularly when problems involve double-digit numbers (Ashcraft & Stazyk, 1981; Torbeyns, Verschaffel, & Ghesquière, 2004). Children who use this strategy tend to have a better understanding of the base-10 structure of the number system than those who do not use it (Laski et al., 2014). In fact, children and adults who frequently use decomposition to solve arithmetic problems tend to have higher math performance and overall math achievement scores than those who depend on counting strategies (Carr & Alexeev, 2011; Carr, Steiner, Kyser, & Biddlecomb, 2008; Geary, Hoard, Byrd-Craven, & DeSoto, 2004; Fennema, Carpenter, Jacobs, Franke, & Levi, 1998). Thus, examining the frequency with which children use decomposition to solve arithmetic problems provides insight into their overall mathematics knowledge.

Study Hypothesis and Research Questions

The present study was based on the hypothesis that the Montessori approach may help children to acquire base-10 and place-value understanding, as well as greater arithmetic accuracy, and to use a base-10 decomposition strategy to a greater extent than other traditional, non-Montessori programs. This hypothesis was based on the extent to which Montessori mathematics materials emphasize the base-10 structure of numbers and that children have opportunities to engage with these materials in the pre-primary program (ages 3 to 5 years).

Research indicates that concrete materials can support young children's mathematics learning but that not all materials are equally effective (e.g., Laski & Siegler, 2014; Siegler & Ramani, 2009; Uttal, O'Doherty, Newland, Hand, & DeLoache, 2009). A recent literature review identified four principles that make it more likely concrete materials will be effective for learning: (a) consistent use of manipulatives, (b) introduction of concrete representations of concepts before gradual progression to more abstract representations, (c) avoidance of manipulatives that represent everyday objects, and (d) clear explanation of the relation between the manipulative and the concept it represents (Laski et al., 2015). Further, this paper proposed that the Montessori materials used for teaching number concepts and the base-10 structure follow these principles. For example, the Montessori curriculum uses a small set of materials (e.g., the golden beads) consistently for several years of instruction, beginning with concrete representations of 10 bars and unit beads, and proceeding to more abstract representations using tiles with numerals. The materials used in Montessori instruction for mathematics also have an explicit and consistent system for representing place value through color coding (Laski et al., 2015; Lillard, 2005).

In addition to the quality of materials used in Montessori mathematics instruction, its emphasis on trading in addition also suggested it would engender a stronger understanding of base 10 and arithmetic in early childhood than other programs do. Evidence indicates that explicit instruction on how to use base-10 decomposition strategies for arithmetic is critical for learning how to accurately execute this strategy and for improving understanding of base 10 (Fuson & Li, 2009; Perry, 2000). Montessori math lessons emphasize the trading of units and tens as the preferred approach to multidigit arithmetic, starting with children's very first exposure to these kinds of problems (Montessori & Simmonds, 1917). In contrast, an analysis of the lessons included in typical non-Montessori curricula (e.g., TERC mathematics) found less emphasis on this approach than in the Montessori math program, particularly in kindergarten.

Based on our hypothesis that the Montessori approach may help children acquire base-10 and place-value understanding, as well as greater arithmetic accuracy, and to use base-10 decomposition strategy to a greater extent than other traditional, non-Montessori programs, we tested three specific research questions.

First, in early childhood (kindergarten and first grade), do students from Montessori and non-Montessori schools exhibit differences in (a) use of base-10 materials to represent number, (b) accurate solution of arithmetic problems, (c) strategy choice when solving arithmetic problems, and (d) accurate execution of decomposition strategies?

Second, do the differences in Montessori and non-Montessori approaches to mathematics persist and/or emerge later in more complex problem-solving? Specifically, do students from Montessori and non-Montessori elementary schools exhibit differences in understanding place value, in accurately solving arithmetic problems, and in strategy choice when solving arithmetic problems?

Third, do early differences in understanding of base 10 predict later differences in accuracy on arithmetic problems and place-value representations?

We predicted that, particularly at the end of the three-year cycle (kindergarten and third grade), children from Montessori schools would perform above their same-aged peers on tasks requiring conceptual understanding of base 10 and place value. Additionally, we predicted that children with greater base-10 knowledge would also be more likely to use decomposition strategies when solving addition problems.

Method

Participants

The study included a large group of kindergartners and first graders ($N = 150$) from Montessori and non-Montessori schools in a northeastern city. As shown in Table 1, 77 kindergartners (Montessori: $n = 48$; non-Montessori: $n = 29$. M_{age} = 6 years, 2 months) and 73 first graders (Montessori: $n = 56$; non-Montessori: $n = 17$. M_{age} = 7 years, 2 months) were included at Time 1 (T1). Approximately 30% of these children were tested again two years later at Time 2 (T2). Two cohorts of children participated at both T1 and T2. One cohort (Montessori: $n = 15$; non-Montessori: $n = 8$) was assessed at T1 as kindergartners (M_{age} = 6 years, 2 months) and again at T2 as second graders (M_{age} = 8 years, 5 months). The second cohort (Montessori: $n = 17$; non-Montessori: $n = 13$) was assessed at T1 as first graders (M_{age} = 7 years, 1 month) and again at T2 as third graders (M_{age} = 9 years, 4 months). There were no significant differences between the ages of children in the two programs at any grade level.

Table 1

Descriptive Information of Participants Included at Time 1 (T1) and Time 2 (T2)

	T1		T2	
	Kindergarten	First Grade	Second Grade	Third Grade
Montessori *n*	48	56	15	17
Non-Montessori *n*	29	17	8	13
Mean Age (months)	74	86	101	112

Procedure

Time 1. At Time 1 (T1), when children were in kindergarten or first grade, two tasks were administered over two sessions: a base-10 block task and an addition task.

In the base-10 block task, an experimenter presented children with unit blocks and 10 blocks and explained that the blocks could be used to show numbers. The experimenter took 10 unit blocks from the tray and lined them up against a 10 block while counting from 1 to 10 to demonstrate that one long block was the same as 10 small blocks. After being introduced to the task with two practice trials, each child was given five test trials. On each test trial, the experimenter presented a child with a different number card and asked the child to represent the number using blocks. The five trials included a random presentation to a child of the numbers 12, 16, 28, 34, and 61. The experimenter recorded how many unit blocks and 10 blocks the child used to represent each number and made notes about the child's response. For each trial, the experimenter coded whether the child (a) used only unit blocks, (b) used a canonical base-10 representation, which involved using the largest possible number of 10 blocks to represent tens and unit blocks to represent ones (e.g., showing 23 with two 10 blocks and three unit blocks), (c) used a noncanonical base-10 representation, which involved some base-10 blocks but not the maximum number, as well as unit blocks (e.g., showing 23 with one 10 block and thirteen unit blocks), or (d) none of the above.

In the addition task, children were presented with a series of individual addition problems, each problem printed on a separate piece of paper. The experimenter read each problem aloud and then gave children as much time as needed to solve the problem. Children were not provided with any supplies, such as paper or pencil, but were permitted to use their fingers or count aloud. The experimenter observed the child and recorded any overt signs of strategy use (e.g., if the child counted aloud, the tester noted use of a counting strategy). When there were no overt behaviors, the tester asked the participant how he or she figured it out after an answer was provided. Each problem was scored for accuracy. In addition, the experimenter coded the strategies children used as one of five categories: *count all*, *count-on*, *decomposition*, *retrieval*, and *other*. The count-all strategy was used when a child counted out each addend and then counted the total (e.g., to solve 5 + 3, a child would first count to 5, then count to 3, then finally count from 1 to 8). The count-on strategy was used when a child counted up from one addend the value of the second addend (e.g., to solve 5 + 3, a child would count from 6 to 8). Decomposition was used when a child transformed the original problem into two or more simpler problems, using either a previously memorized number fact or the base-10 properties of the number system (e.g., to solve 7 + 6, a child might first add 7 + 3 to get 10 and then add 3 more to arrive at 13). Retrieval was used when a child recalled the solution from memory. If a child guessed or used a strategy that could not be coded into one of the previous categories, the strategy was coded as other.

Time 2. At Time 2 (T2), when they were in second or third grade, children completed fifteen problems: five place-value problems (e.g., "Circle the largest number: 10101, 1901, 93001, 1899.") and ten arithmetic problems. In the set of arithmetic problems, five double-digit and mixed-digit addition and subtraction problems were contextualized within a story (e.g., "A grocery store had 89 bananas. It sold 27 bananas on Monday and 34 bananas on Tuesday. How many bananas were left in the grocery store on Wednesday?"). The remaining five arithmetic problems were decontextualized, where children were presented with double-digit addition, subtraction, and missing-term problems (e.g., 42 – 29 = ?) using only numerical symbols. Children were permitted to solve the problems either mentally or with the paper and pencil provided. For each problem, experimenters followed the same procedure used at T1 to evaluate children's accuracy and strategy use, with two differences in procedure. The first difference was to not code retrieval. The problems used double-digit numbers, and it is believed that children are able to recall answers only on simple problems (e.g., Geary et al., 2004). The second difference was the use of the code *written algorithm* when children wrote or described the written algorithm (e.g., "I lined up the numbers in my head and carried the one….").

Results

Research Question 1

To answer our first research question, we examined whether there were program and grade-level differences in accuracy on the base-10 block task and arithmetic, as well as strategy choice and accuracy when using a decomposition strategy. For this research question, we were interested in examining only the data from T1, so we used the entire sample ($N = 183$).

Base-10 Knowledge. We ran a 2 (grade: kindergarten vs. first) × 2 (program: Montessori vs. non-Montessori) ANOVA on the percentage of block-task problems for which children correctly used a canonical representation of base 10. We found a main effect for grade, $F(1, 178) = 39.47$, $p < .001$, $\eta_p^2 = .18$ and a grade-by-program type interaction, $F(1, 178) = 14.32$, $p < .001$, $\eta_p^2 = .07$. Figure 1 presents the children's average accuracy, separated by grade and program type. First graders used accurate canonical representations on a greater percentage of trials than kindergartners, 90% (*SD* = 28) versus 56%, (*SD* = 43), respectively, $p < .001$. This effect varied by program: first graders who attended non-Montessori schools were more likely to use canonical representations than their kindergarten counterparts, $p < .001$, but there were no grade-level differences between both kindergartners and first graders attending Montessori programs. In other words, between kindergarten and first grade, children in non-Montessori programs demonstrated a substantial increase in their use of canonical representations (44% [*SD* = 43] to 94% [*SD* = 28] of trials), whereas Montessori children did not. This finding may be attributable in part to Montessori children having less room for improvement than non-Montessori children. In kindergarten, children from Montessori schools used correct canonical representations on 28% more problems compared to children from public schools. In sum, children who attended Montessori programs demonstrated an advantage in base-10 understanding in kindergarten relative to their non-Montessori peers, but non-Montessori children improved by the end of first grade such that there was no longer a difference between programs.

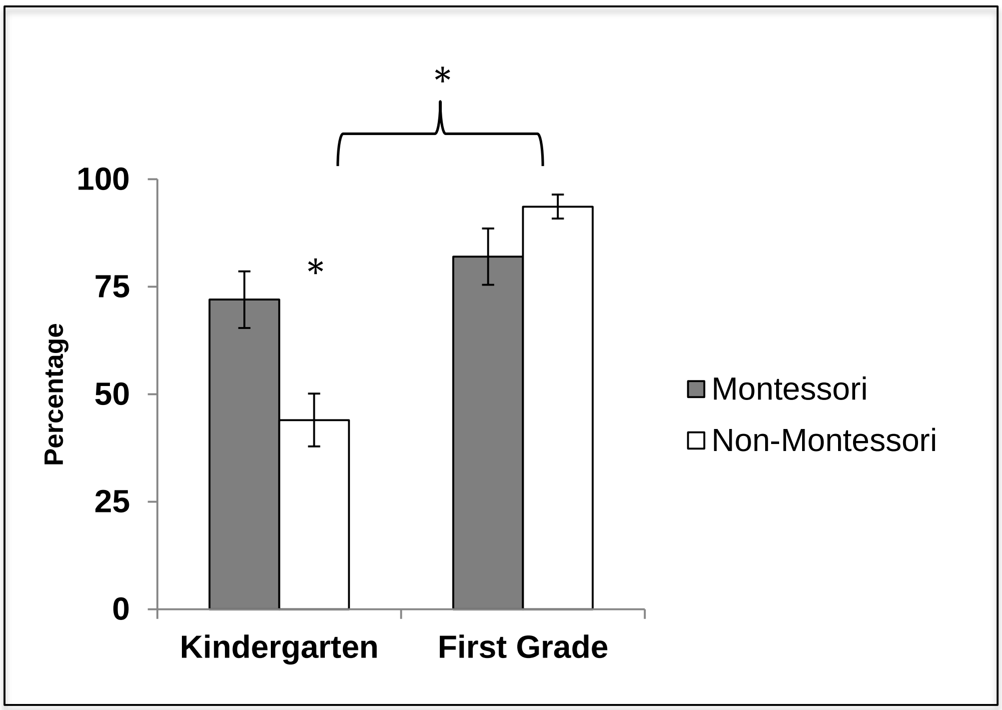

Figure 1. Percentage of correct base-10 canonical representations of base 10 at T1. Error bars represent standard error.
* $p < .001$.

Arithmetic Accuracy. A 2 (grade: kindergarten vs. first) × 2 (Program: Montessori vs. non-Montessori) ANOVA on the percentage of problems answered correctly found a main effect for grade, $F(1, 178) = 43.62$, $p < .001$, $\eta_p^2 = .20$. First graders correctly answered more addition problems than did kindergartners, $p < .001$, 87% vs. 63%.

Arithmetic Strategy. A 2 (grade: kindergarten vs. first) × 2 (program: Montessori vs. non-Montessori) MANOVA on the percentage of problems for which children used a *counting*, *decomposition*, *retrieval*, or *other* strategy found a multivariate main effect for grade, $F(4, 175) = 16.57$, $p < .001$, $\eta_p^2 = .27$, such that the distribution of strategies used by children changed between kindergarten and first grade. To better understand the multivariate effect, we examined the result of the univariate analyses and found main effects for grade for each strategy type. Kindergartners used counting, $F(1, 178) = 25.98$, $p < .001$, $\eta_p^2 = .13$, and other, $F(1, 178) = 6.30$, $p = .01$, $\eta_p^2 = .03$, more frequently than first graders; counting and other were used on 65% ($SD = 31$) and 11% ($SD = 20$) of addition problems by kindergartners but on 39% ($SD = 31$) and 5% ($SD = 8$) percent by first graders. In contrast, first graders used decomposition, $F(1, 178) = 38.03$, $p < .001$, $\eta_p^2 = .18$, and retrieval, $F(1, 178) = 45.59$, $p < .001$, $\eta_p^2 = .20$, more frequently than kindergartners; decomposition and retrieval were used on 10% ($SD = 18$) and 9% ($SD = 11$) of addition problems by kindergartners but on 32% ($SD = 25$) and 23% ($SD = 14$) by first graders. There was no main effect for program or program-by-grade interaction. Thus, first graders were more likely to use sophisticated strategies than kindergartners, regardless of program, and at each grade Montessori and non-Montessori students used similar strategies to solve the addition problems. Figure 2 presents the average percentage of trials for which kindergartners and first graders used each type of strategy.

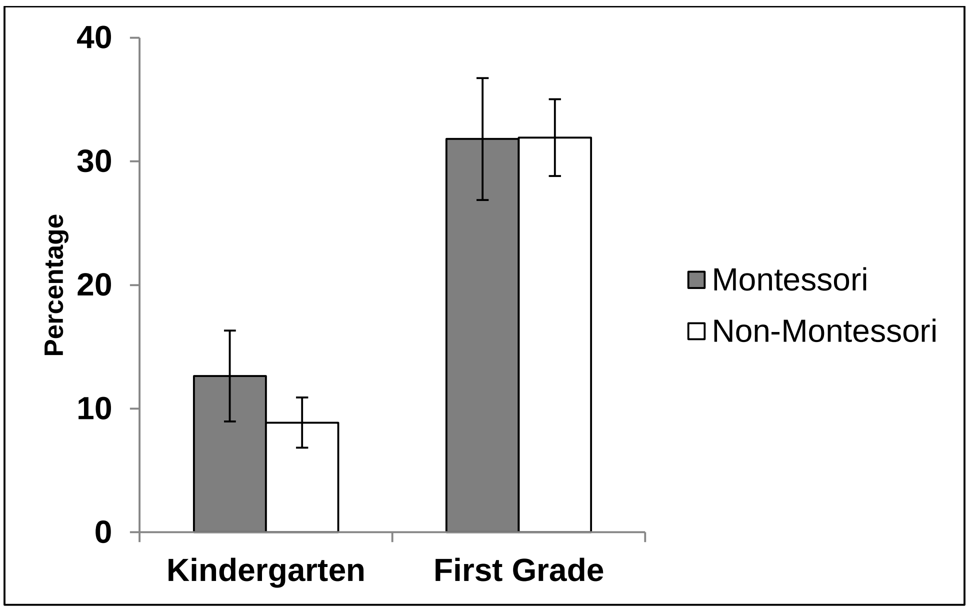

Figure 2. Percentage of problems on which children used a decomposition strategy at T1.

Decomposition Accuracy. A 2 (grade: kindergarten vs. first) × 2 (program: Montessori vs. non-Montessori) ANOVA on the percentage of problems for which children correctly used a decomposition strategy found a main effect for grade, $F(1, 175) = 36.10$, $p < .001$, $\eta_p^2 = .17$, but no main effect for program or grade-by-program interaction. First graders used a decomposition strategy correctly on 32% ($SD = 25$) of the problems on which they attempted it, whereas kindergartners executed the strategy correctly on only 11% ($SD = 19$) of the problems on which they attempted it.

Research Question 2

To answer our second research questions about whether children who have experienced Montessori approaches to mathematics through primary school demonstrate later advantages, we examined whether there were program and grade-level differences in accuracy on the place-value and arithmetic problems at second and third grades.

Place-Value Knowledge. A 2 (grade: kindergarten vs. first) × 2 (program type: Montessori vs. non-Montessori) ANOVA on accuracy on place-value problems found no main effects for grade or problem type, and there was no interaction between grade and program..

Arithmetic Accuracy. Preliminary analyses revealed no differences in children's accuracy on contextualized and decontextualized problems; thus, these two categories were combined to form an overall arithmetic measure. A 2 (grade: second vs. third) × 2 (program type: Montessori vs. non-Montessori) on the percentage of arithmetic problems answered correctly found a main effect for grade, $F(1, 49) = 5.66$, $p = .02$, $\eta_p{}^2 = .10$. Second graders accurately answered 64% ($SD = 32$) of problems, whereas third graders accurately answered 81% ($SD = 19$) of problems. There was no main effect for program and no interaction between program and grade.

Arithmetic Strategy. Finally, we examined grade and program differences on the percentage of arithmetic problems on which children used a counting, decomposition, written algorithm, or other strategy. A 2 (grade: second vs. third) × 2 (program type: Montessori vs. non-Montessori) MANOVA found a multivariate effect of grade, $F(4, 46) = 5.68$, $p = .001$, $\eta_p{}^2 = .33$ and a trend for a grade-by-program interaction, $F(3, 46) = 2.50$, $p = .06$, $\eta_p{}^2 = .18$.

To better understand the multivariate effect, we examined the result of the univariate analyses and found a main effect of grade in the frequency with which children used a counting strategy, $F(1, 49) = 10.37$, $p = .002$, $\eta_p{}^2 = .18$. Children used counting on 14% ($SD = 20$) of problems in second grade and 2% ($SD = 6$) of problems in third grade. We found a grade-by-program interaction for use of a written algorithm strategy. Children in Montessori schools used written algorithm on about 46% of problems in both second and third grades. However, children's percentages in non-Montessori schools increased from using written algorithm on 25% ($SD = 29$) of problems in second grade to 77% ($SD = 28$) of problems in third grade. Figure 3 presents the percentage of problems on which children chose to use a written algorithm strategy by program type and grade. When looking at the percentage of problems on which children were coded as using other strategies, there was both a main effect for grade, $F(1, 49) = 10.14$, $p = .003$, $\eta_p{}^2 = .17$, and a grade-by-program interaction, $F(1, 49) = 4.2$, $p = .046$, $\eta_p{}^2 = .08$. Overall, children used other strategies on 6% ($SD = 14$) of problems in second grade and on 0.7% ($SD = 4$) of problems in third grade. Children's use of other strategies in non-Montessori programs decreased by 10%, while the use of other strategies by children in Montessori programs decreased by less than 3%.

Research Question 3

To examine whether early differences in performance might be related to later ones, we ran a series of correlational analyses between children's performance on assessments at T1 and their performance on assessments at T2. In particular, we were interested in whether base-10 knowledge in kindergarten and first grade predicted arithmetic performance in second and third grades and whether this relation varied by program type. These analyses included only the subgroup of children who participated in both the T1 and T2 studies.

Cohort 1. As shown in Table 2, for cohort 1 we found that the percentage of trials in which kindergartners used base-10 canonical representations of number was positively correlated with accuracy on arithmetic problems in second grade among children from non-Montessori programs and for accuracy on arithmetic and place-value problems in second grade among children in Montessori programs. In addition, accuracy on addition problems in kindergarten was positively correlated with accuracy on arithmetic problems in second grade among children in non-Montessori programs. However, accuracy on addition problems at T1 was not correlated with any T2 measures among children from Montessori programs. Finally, the percentage of trials in which children used a decomposition strategy in kindergarten was not correlated with accuracy on any type of arithmetic problem in second grade among children from non-Montessori programs or Montessori programs.

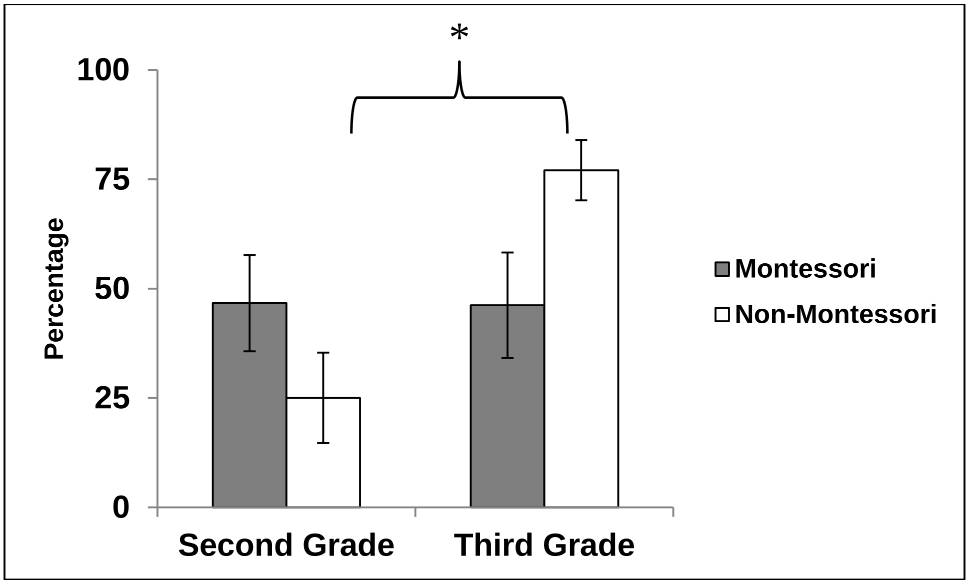

Figure 3. Percentage of problems on which children used a written algorithm strategy at T2.

Cohort 2. We ran identical correlation analyses for children from cohort 2. As Table 2 shows, the percentage of trials in which first graders used base-10 canonical representation of numbers as well as accuracy on the T1 arithmetic assessment were both correlated with accuracy on place-value problems among third graders in non-Montessori programs. However, base-10 canonical representation and T1 arithmetic accuracy were not correlated with any T2 measures among third graders from Montessori programs. The percentage of trials in which first graders used a decomposition strategy was not correlated with any third-grade measures among children from non-Montessori programs but was correlated with accuracy on arithmetic problems and place-value problems in third grade among children from Montessori programs.

Table 2

Correlation Coefficients (Pearson's r*) Between Accuracy Percentages on Assessments from Time 1 (T1) and Time 2 (T2)*

Kindergartners and second graders from non-Montessori programs

	1	2	3	4	5
1. T1 Base-10 Canonical Representation	-				
2. T1 Arithmetic	0.924**	-			
3. T1 Decomposition	0.592	0.478	-		
4. T2 Arithmetic	0.948**	0.799*	0.403	-	
5. T2 Place Value	0.552	0.522	0.622	0.713*	-
6. T2 Decomposition	0.587	0.473	0.408	0.455	–0.032

Kindergartners and second graders from Montessori programs

	1	2	3	4	5
1. T1 Base-10 Canonical Representation	-				
2. T1 Arithmetic	0.458	-			
3. T1 Decomposition	0.352	0.451	-		
4. T2 Arithmetic	0.600*	0.426	0.506	-	
5. T2 Place Value	0.725**	0.394	0.491	0.834**	-
6. T2 Decomposition	0.317	0.195	–0.073	0.194	0.29

First and third graders from non-Montessori programs

	1	2	3	4	5
1. T1 Base-10 Canonical Representation	-				
2. T1 Arithmetic	0.458	-			
3. T1 Decomposition	0.419	0.686**	-		
4. T2 Arithmetic	0.224	0.317	0.112	-	
5. T2 Place Value	0.560*	0.505*	0.406	0.491*	-
6. T2 Decomposition	0.286	0.34	0.444	0.121	0.416

First and third graders from Montessori programs

	1	2	3	4	5
1. T1 Base-10 Canonical Representation	-				
2. T1 Arithmetic	0.204	-			
3. T1 Decomposition	–0.041	0.732**	-		
4. T2 Arithmetic	0.220	0.409	0.577*	-	
5. T2 Place Value	0.03	0.302	0.664*	0.718*	-
6. T2 Decomposition	0.253	0.284	0.316	–0.417	–0.005

Note: T1 represents tasks from Time 1; T2 represents tasks from Time 2. T1 and T2 decomposition refer to the percentages of trials in which children used a decomposition strategy, regardless of whether they accurately answered the problem.
* $p < .05$ level, two-tailed
** $p < .01$ level, two-tailed

Discussion

This study tested the hypothesis that the Montessori approach promotes better base-10 and arithmetic understanding than other traditional programs, given the emphasis of these concepts in Montessori materials and instruction. Overall, the study found no evidence in support of this hypothesis. By first grade and through the end of third grade, no differences were found in the mathematics knowledge of children from Montessori and non-Montessori programs. In the discussion that follows, we offer potential explanations for and implications of the findings.

Early but Not Later Differences in Base-10 Understanding

The results of this study revealed that children in Montessori programs showed an advantage in base-10 understanding in kindergarten, as compared with peers from more traditional schools. However, Montessori students did not show the same advantage in first, second, and third grades. There are several possible explanations for this finding. First, the specific group of Montessori kindergartners who participated in this study might have been particularly advanced. This explanation seems unlikely, however, because the same children were tested in second grade and showed no advantage at that time. A more plausible explanation is that Montessori might have an especially strong preschool program or that more of the Montessori kindergartners had experienced preschool instruction, given that kindergarten is the final year in the three-year cycle, giving children in kindergarten an advantage over their peers from other programs. However, by first grade, non-Montessori peers might have had enough time to catch up.

The pattern of correlations between base-10 understanding at T1 and place-value knowledge at T2 support this "catch-up" explanation. The place-value assessment given to children in second and third grades was designed to be an age-appropriate test analogous to the base-10 assessment used in kindergarten and first grade. We predicted children who used canonical base-10 representations in kindergarten and first grade would perform more accurately on place-value problems two years later. We found that the percentage of canonical base-10 representations in kindergarten was correlated with place-value performance, but not other skills, in second grade among children from Montessori schools; the percentage of canonical representations of base-10 in first grade was positively correlated with place-value accuracy, but not other outcomes, for third graders from non-Montessori schools. This different pattern of correlations supports the view that Montessori children acquired these concepts primarily in kindergarten, whereas non-Montessori students did so in first grade. Importantly, second graders from both schools performed equally as accurately on the place-value assessment, suggesting that timing of acquisition had little-to-no effect on later performance.

Another explanation, not mutually exclusive, may be that the Montessori approach focuses on a wider range of math concepts than typical non-Montessori instruction during this time period, in other words, children receive differential practice in base 10 across programs. Further research with a larger number of students is necessary to gain insight into why this Montessori advantage existed in kindergarten but not in elementary school. It would also be worthwhile to examine differences on broader measures of mathematics achievement.

Longitudinal Patterns of Arithmetic Accuracy and Strategies

While there were no differences in arithmetic accuracy between children from Montessori and non-Montessori schools at either T1 or T2, children from the different programs did exhibit different developmental trajectories. Arithmetic accuracy in kindergarten appeared to predict arithmetic accuracy in second grade for children from non-Montessori schools but not for children from Montessori schools. This finding suggests that, in more traditional school settings, teaching practices and curricula might require children to build upon past knowledge when learning to solve more advanced problems. By the middle of elementary school, children who did not develop basic arithmetic understanding at the start of schooling might have a challenging time accurately solving more advanced problems. Likewise, those children who were particularly advanced in kindergarten might be able to use their early knowledge to continue to succeed. However, results from this study suggest that early arithmetic ability is not predictive of advanced problem-solving skills for children in Montessori programs. Montessori teaching practices might encourage children to draw from a range of skills other than arithmetic ability to solve more advanced arithmetic in middle elementary school or might consistently review arithmetic skills over the three-year period, making kindergarten skill-level less influential.

Despite not exhibiting differences in arithmetic accuracy, children in Montessori and non-Montessori programs executed different strategies to obtain their answers in second and third grades. Strategy use did not differ by program type in kindergarten and first grade. In both second and third grades, children in Montessori schools showed a fairly even split between using written algorithms and decomposition strategies. However, in non-Montessori schools, children shifted from using a combination of written algorithm, decomposition, and counting strategies in second grade to using a written algorithm strategy on approximately three quarters of problems in third grade. These results suggest that Montessori curriculum may emphasize the use of algorithms to solve problems less than non-Montessori schools do. This difference may be because Montessori programs continue to use concrete materials throughout the early elementary school years more than non-Montessori programs. Importantly, there seemed to be no disadvantage in the shift toward written algorithms for non-Montessori children: these children demonstrated accuracy and place-value knowledge comparable to that of Montessori children. Further research is necessary to understand whether the strategies children use to execute arithmetic problems in third grade are predictive of math outcomes later in elementary school.

Implications for Montessori Education

In sum, the results from this longitudinal study indicate that the Montessori approach may offer an early advantage over non-Montessori programs in helping children understand critical math concepts, but this gain does not translate into a long-term advantage. The findings raise at least two questions for Montessori educators to consider.

First, as children transition to elementary programs, what can be done to maintain and build on the advantage kindergartners demonstrate in base-10 understanding? Children from Montessori schools did not demonstrate improvement on base-10 understanding between kindergarten and first grade, despite not being at ceiling in kindergarten. In contrast, children in non-Montessori programs demonstrated substantial improvement between kindergarten and first grade. Further, it is important to note that the advantage did not re-emerge at the end of the three-year cycle: no difference remained in place-value understanding between Montessori and non-Montessori children in third grade. A better understanding of what happens when children transition from the Children's Garden to the elementary program is needed. There may be unnecessary repetition in lessons; alternatively, the transition to abstract representations could occur more rapidly.

Second, how can instruction help children generalize and transfer their understanding of bead bars and units to arithmetic tasks and strategies? Previous research has demonstrated that kindergartners' representation of base 10 contributes to the frequency with which they attempt to solve arithmetic problems with base-10 decomposition (Laski et al., 2014). However, in the current study, decomposition at T1and T2 were not correlated with base 10 or place value for any group of children in this study.

There is increasing evidence that children require explicit guidance and instruction to abstract concepts from concrete materials or to see connections between two concepts (Carbonneau, Marley, & Selig, 2013; DeLoache, Peralta de Mendoza, & Anderson, 1999; Laski & Siegler, 2014). According to the cognitive-alignment framework, a theoretical framework for instructional design, even if the concrete materials are ideally designed, learning is unlikely to occur if procedures and didactic statements do not direct children's attention to the relevant features (Laski & Siegler, 2014). Thus, educators should consider how to explicitly show children that their base-10 knowledge is beneficial in the use of decomposition for mentally solving addition problems.

Conclusion

Children educated with Montessori curricula or with more mainstream curricula likely receive very different instruction when learning foundational math concepts. This study reveals similar levels of accuracy in arithmetic and place value for both Montessori and non-Montessori students. These results demonstrate that there are many different, effective ways to approach early math education. Future research spanning a longer time frame and more complex concepts might shed greater light on whether there are lasting effects of different educational approaches.

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Removing Supplementary Materials from Montessori Classrooms Changed Child Outcomes

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***Keywords**: cognitive development, executive function, reading, fidelity of implementation*

Abstract. Montessori classrooms vary in the degree to which they adhere to Maria Montessori's model, including in the provision of materials. Specifically, some classrooms use only Montessori materials, whereas others supplement the Montessori materials with commercially available materials like puzzles and games. A prior study suggested such supplementation might explain observed differences across studies and classrooms (Lillard, 2012), but an experimental study is the best test of this possibility. Here we present such an experiment, with 52 children in three Montessori classrooms, all of which included supplementary materials at the start of the study. Non-Montessori materials were then removed from two of the classrooms, and all children were given six pretests as a baseline. Four months later, children were retested to see how much they had changed across that period. Children in the classrooms from which the non-Montessori materials were removed advanced significantly more in early reading and executive function and advanced to some degree more in early math than children in the other two classrooms. There were no differences across the classroom types in amount of change on the tests of vocabulary, social knowledge, or social problem-solving skills.

Although virtually all Montessori classrooms share some features, like giving children some choices about what work they do and when they do it, classrooms can also vary a great deal. One of the dimensions along which they vary is the materials offered, with some classrooms including toys and puzzles in addition to the Montessori materials. Lillard (2011), in an effort to establish an agreed-upon core set of Primary classroom materials, created a teacher questionnaire that listed dozens of materials seen in Primary Montessori classrooms. The survey asked 29 Primary-level teacher trainers—59% at American Montessori Society (AMS) training centers and the rest at Association Montessori Internationale (AMI) training centers—to describe each material as *necessary*, *desirable*, *acceptable*, or *best avoided* in a Primary-level classroom.

Although there was not 100% agreement (even within training types), at least 85% of all the teacher-trainers agreed a large core set belongs in a Montessori Primary classroom. At issue is whether child outcomes differ when classrooms include materials beyond this core set.

One reason this study is of interest is that using only Montessori materials could reflect fidelity of implementation, and fidelity might explain inconsistent results observed across studies of Montessori outcomes. Some studies have found that children attending Montessori schools have better outcomes than other children. For example, Dohrmann and colleagues looked at standardized test scores and grades for Milwaukee high school students who, years earlier, had attended public Montessori or other schools (Dohrmann, Nishida, Gartner, Lipsky, & Grimm, 2007). They found that the Montessori students scored significantly higher in math and science, and slightly (but not significantly) higher in social studies and English compared to age-matched peers. Lillard and Else-Quest (2006) compared children who had lost a lottery to attend a Montessori school with children who gained admission; they found several significant differences at ages 5 and 12, all favoring children in Montessori. Other studies have also shown positive results for Montessori children (Besançon & Lubart, 2008; Brown & Steele, 2015; Miller & Bizzell, 1984; Rathunde & Csikszentmihalyi, 2005a, 2005b; Rodriguez, Irby, Brown, Lara-Alecio, & Galloway, 2005). However, some studies have not shown better outcomes for children in Montessori programs. For example, Lopata and colleagues found that Montessori children scored lower in reading in eighth grade than did children in other programs (Lopata, Wallace, & Finn, 2005). Krafft and Berk (1998) found less private speech (a self-regulatory activity) in Montessori children compared to children in a play-oriented preschool program (see also Cox & Rowlands [2000] and early results from the 1970s Head Start). However, the Montessori implementation in these latter cases appeared to be of low fidelity. For example, Krafft and Berk described children's work occurring over a single 45-minute period at work stations; the work period was thus too short, and work stations are not part of Montessori education. Another study, which found better outcomes for Latino students in Montessori versus traditional schools and equal outcomes for African-American students, had single-aged classrooms, and other features of implementation fidelity were not well addressed ("We believe [the programs were] rigorous," Ansari & Winsler, 2014, p. 5). In sum, a possible explanation for different outcomes is that the research showing less positive outcomes was conducted at schools in which Montessori implementation was of low fidelity.

Fidelity in Montessori can be measured in many ways, and currently there is no single, accepted measure. As mentioned above, the materials a program offers and uses can be one index. One study compared Primary children in three classic Montessori classrooms (offering exclusively Montessori materials as determined by Lillard [2011]) with children in nine supplemented Montessori classrooms (offering a variety of other materials, such as worksheets, commercial puzzles, and crafts, in addition to Montessori materials). In fall and spring, children were given a wide variety of tests that assessed early academic and socioemotional competence, allowing measurement of change across the school year. In the classic classrooms, children were engaged with Montessori materials almost 100% of the time, whereas in the supplemented classrooms, engagement with Montessori materials ranged from 38%–56% of the time. The gain from fall to spring was higher among classic Montessori children on every variable tested—significantly so for most variables. The Head–Toes–Knees–Shoulders (HTKS) test of executive function, for example, is a Simon Says-type game in which children must do the opposite of what the experimenter tells them to do; for instance, children must touch their toes when the experimenter says, "Touch your head!" From fall to spring, children in classic Montessori gained on average almost 14 points (equivalent to following an additional seven out of 40 commands correctly compared to their fall performance), whereas supplemented Montessori children gained an average of just 7 points, or 3.5 commands. The Letter–Word test of early reading, a subscale of the Woodcock–Johnson Tests of Achievement III (WJ III; Woodcock, McGrew & Mather, 2001) also showed particularly strong gains for classic Montessori children, as did the Picture Vocabulary test.

At issue is whether the presence of only Montessori materials caused these different levels of gain, or whether some other "third variable" was responsible for the differences. Lillard (2012) proposed materials as an index of fidelity; yet, in and of themselves, the materials might not be important. Perhaps teachers who choose to have only Montessori materials in their classrooms also adhere more tightly to other aspects of the Method, and it is those aspects, rather than the materials, that led to the larger gains.

To examine this issue, in the present study a Head of School at a school with three Primary classrooms removed all non-Montessori materials from two of those classrooms over a weekend. Researchers tested children immediately after this change was made and again 4 months later. Changes in children's scores across the 4 months in the two classrooms from which the non-Montessori materials were removed were compared with changes in the one classroom in which the non-Montessori materials remained.

Method

Participants

Fifty-five children completed pretest assessments in the first 2 weeks after they returned from the winter holiday; 53 of these children took posttests 4 months later, in the final weeks of the school year (the remaining two children were absent during the retest period). In addition, one child performed much worse in the spring on four of five tests, suggesting error (child not trying or incapacitated) given that children typically improve on these tasks with age; this child was also excluded from all analyses. The final sample of 52 children had a mean age in January of 57.4 months (*SD* = 13.2, range 31–83 months, 27 boys). Of these, 45% were 3-year-olds, 36% were 4-year-olds, and 18% were 5-year-olds. Breaking down this demographic by subsample, there were 35 children in the two classrooms from which materials were removed (M_{age} = 56.9 months, *SD* = 14.0, range = 31–83 months, 16 boys). In the unchanged classroom, there were 17 children (M_{age} = 58.2 months, *SD* = 11.7, range = 40–77 months, 11 boys). The percentages of children and mean ages at each age level in each type of class were about the same. Ethnicity data were not collected, but the school's demographic representation is similar to that of the local community: about 70% white, 20% African American, 5% Asian, and 5% multiracial or other races.

Materials and Procedure

Participants were children from three Primary classrooms (3 to 6 years) at a Montessori school that used non-Montessori materials in all classrooms. The Head of School volunteered to test the hypothesis that removing materials would influence child outcomes. Prior to removing materials and then again well into the spring semester, four classroom "snapshots" were taken, in which an observer noted what each child in each classroom was doing; the percentage of children engaged with Montessori materials and the percentage engaged with supplementary materials were calculated.

Two teachers agreed to have supplementary materials removed from their classrooms. Children in the different classrooms performed similarly on all pretests, and key teachers in both types of classrooms had taught Primary children at the school for more than 10 years. Parents received a cover letter from the Head of School, a letter from the researchers describing the study, and an informed consent form. All children with parental consent participated (see prior section); participation rates ranged from 65% to 75% across the three classrooms. The testers were blind to the intervention and the study hypotheses, except that the first author conducted one participant's pretest as part of the research assistant training. Testing occurred in January and May of a single school year.

Setting. Each classroom in the school had two trained Montessori teachers and 24 to 27 children in each classroom. All teachers were certified by a major Montessori organization (AMI or AMS). The school implemented the Montessori program with some deviations. The primary deviations from the program described in Montessori's books were (a) the use of two trained teachers, rather than one teacher and one untrained assistant; (b) the replacement of work periods with specials—art, music, and Spanish—three times a week (out of 10 work periods); and (c) the supplementary non-Montessori materials, removed from two classrooms for the experiment. Examples of these supplementary materials include a basket of small, plastic ladybugs intended for counting; cassette players and head phones for listening to stories while looking at books; commercial puzzles; commercial building blocks; a plastic baby doll with a washtub; and worksheets of Montessori materials for coloring.

Measures. Six measures were given in a fixed order at both pretest and posttest to assess social cognition (theory of mind), social problem solving, executive function, reading, vocabulary, and math.

Theory of mind. Social cognition or theory of mind was assessed using the theory of mind scale (Wellman & Liu, 2004). This set of tasks is designed to measure an understanding of others' minds and emotions. Researchers administered four of the five tasks in the scale: knowledge access, contents false belief, not-own belief, and real–apparent emotion. We omitted the first task, not-own desire, because all children of the ages tested were expected to pass it. For the knowledge access task, the experimenter first showed the child a toy drawer and asked what he or she thought was in the drawer. The experimenter revealed the true contents of the drawer (a small toy dog at pretest and a toy frog at posttest) and then placed the item back in the drawer. The experimenter then presented the child with a small doll and said the doll had never seen inside the drawer before. The test questions asked whether the doll knew what was in the drawer and whether the doll had seen inside the drawer; children received 1 point for a *no* answer to each question. For the contents false belief task, the experimenter showed the child a box of Band-Aid adhesive bandages that contained a toy pig at pretest, and a box of crayons that contained a brush at posttest. After the child was shown the contents, the box was closed again. The experimenter told the child that a doll had never seen inside the box before and asked the child what the doll thought was inside (1 point) and whether the doll had seen inside (1 point). In the not-own belief task, the experimenter asked the child if he or she believed that a cat would be hiding in a garage or in some bushes (each scenario was shown in a picture). The experimenter told the child that a doll believed the opposite of what the child believed; the child then was asked where the doll would search for the cat (1 point). For the real–apparent emotion task, the experimenter presented three simple faces that were labeled *happy*, *sad*, and *okay*, based on mouth appearance. At pretest, children were told that a boy's aunt

> promised that she would buy Matt a toy car. But, she got Matt a t-shirt instead. Matt doesn't like t-shirts. What Matt really wants is a toy car. But, Matt has to hide how he feels, because if his aunt knows his real feelings, she'll never buy him anything again[1].

After a memory check asking about what Matt wanted, what he got, and what would happen if his aunt knew how he really felt, each child was asked to point to the face that showed how Matt really felt (1 point) and how his face looked (1 point). The posttest story was structurally the same but involved Joey's uncle giving him a ball instead of a bicycle.

Executive function. Executive function was assessed using the HTKS task (Cameron Ponitz et al., 2008; Ponitz, McClelland, Matthews, & Morrison, 2009). Children were instructed that when the experimenter says, "Touch your head," they should instead touch their toes, and when told "Touch your toes," they should instead touch their heads. Children completed four practice trials with feedback from the experimenter before moving on to 10 test trials without feedback. Each trial was scored from 0 to 2, with 0 indicating that children touched the indicated location, 1 indicating that children initially were incorrect but corrected themselves, and 2 indicating that children immediately touched the opposite of the indicated location as instructed. When children scored at least 10 points, they continued to the Knees–Shoulders part of the task. For this part, additional instructions were given regarding touching their knees and shoulders. They again completed four practice trials on just the knees–shoulders commands, followed by 10 more trials using all four instructions. Possible total scores ranged from 0 to 40.

Social problem solving. One object-acquisition story from the Social Problem Solving Test-Revised (SPST-R) was used (Rubin, 1988). Children featured in the story illustrations matched the

[1] This wording deviates from the wording in Wellman and Liu (2004) but comes precisely from a Theory of Mind Scale script that Wellman and Liu provided to the first author in October 2009, which directs people who use the script to cite Wellman and Liu (2004).

participating child's race and gender, as is customary. Children were told, "[A reading child] has been looking at this book for a long time and [an onlooker] really wants to look at the book. What could [onlooker] do or say so he/she could have a look at the book?" Children's responses were quickly recorded by hand, and then children were asked, "What else could he/she do or say?" and finally, "What if it was you? What could you do or say so you could have a look at the book?" Responses were scored on their number of references to sharing and fairness, as in Lillard (2012), with a possible range from 0 to 3.

Reading, vocabulary, and math. Three subscales (Letter–Word ID, Picture Vocabulary, and Applied Problems) from the Woodcock–Johnson Tests of Achievement III (WJ III), a standardized norm-referenced scale (Woodcock, McGrew, & Mather, 2001), were administered according to the WJ III manual; raw scores were used because gain scores were analyzed.

Results

The classroom snapshot coding revealed that removing supplementary materials greatly reduced the time spent with non-Montessori materials. Prior to removing the materials, children were engaged with supplementary non-Montessori materials about 25% of the time and engaged with Montessori materials 34% of the time—the remaining time was spent in specials, outside, and so on. After the materials were removed from two classrooms, children in those classrooms were engaged with Montessori materials 58% of the time, and use of supplementary materials was minimal. (Apparently, some supplementary materials had reappeared, as 5% of the time children were using them!) In the unchanged classroom, 42% of activities involved Montessori materials and 24%—about the same as earlier—involved supplementary ones.

Next, we consider child outcomes. In January, children in the two types of classrooms (non-Montessori materials retained versus removed) scored similarly on all the tests except HTKS, on which children in the retained non-Montessori materials classroom performed significantly better (retained M = 29.82, SD = 7.12; removed M = 22.29, SD = 14.23). Thus these children were more advanced at the outset in executive function, but on all five other measures, the scores of children in the two types of classrooms were the same.

Of interest was how much children changed in the remaining 4 months of the school year, after the removal of the non-Montessori materials from two classrooms. Therefore, gain scores were calculated by subtracting the pretest (January) from the posttest (May) scores for each child; t-tests—one-tailed, because we had a specific hypothesis, based on Lillard (2012)—were performed on these scores, comparing children in the classroom that retained its non-Montessori materials with children in the two classrooms that removed the non-Montessori materials. Two tests yielded medium effect-size changes that were significant at the $p < .05$ level, and one yielded a small effect-size change that was nonsignificant given the small sample size.

First, children in the classrooms from which non-Montessori materials were removed advanced significantly more than children from the unchanged classroom over the 4 months in early reading, as indicated by their Letter–Word scores, $t(50) = 1.88$, $p = .035$, Cohen's $d = .58$; see Figure 1. Their Letter–Word scores improved on average by 4.54 points (SD = 4.46), whereas those of children in the unchanged classroom improved by 2.24 points (SD = 3.46).

Second, children in the classrooms in which the non-Montessori materials were removed advanced significantly more on the HTKS test, $t(50) = 1.71$, $p = .047$, Cohen's $d = .51$ (see Figure 2). They improved by a mean of 5.11 points (SD = 9.39), versus a 0.41- (SD = 9.12) point gain for the children in the classroom that retained its non-Montessori materials. This result was not caused by restricted range: Children in both groups were still well below ceiling on HTKS at posttest.

The third result was nonsignificant and yielded a small effect size (Cohen's $d = .19$) so should be viewed more cautiously. Children in the classrooms from which the non-Montessori materials were removed advanced slightly more in their applied math performance (M = 1.34, SD = 1.97) than children in the classroom that retained non-Montessori materials (M = 1.00, SD = 1.54); see Figure 3.

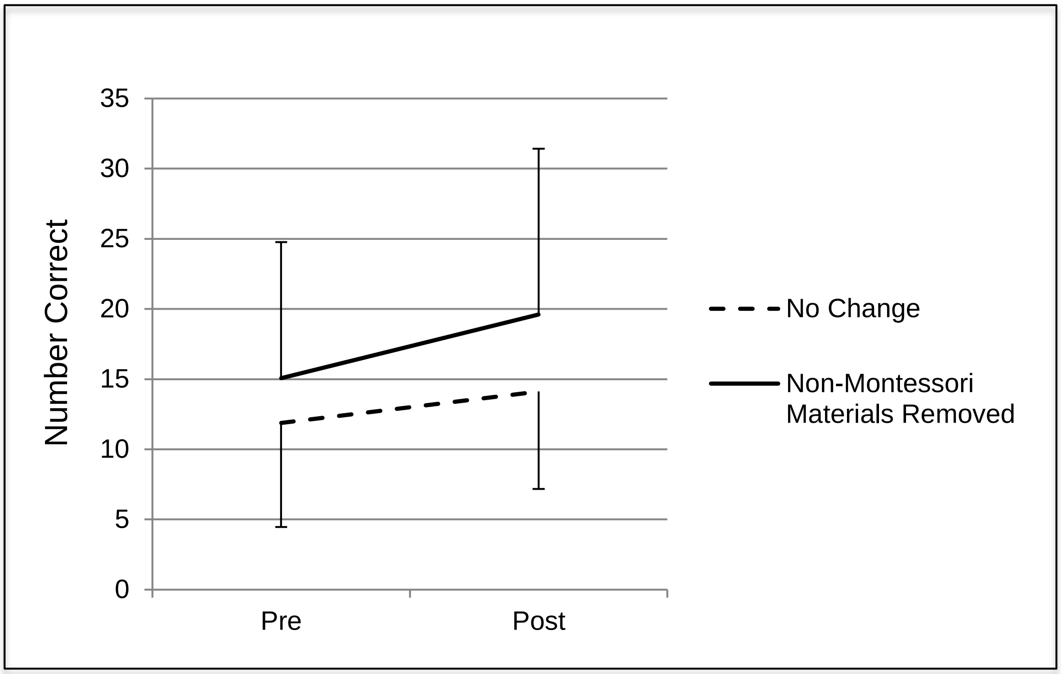

Figure 1. Change in Letter–Word scores from pretest to posttest. *Y*-axis represents number correct; error bars represent *SD*s.

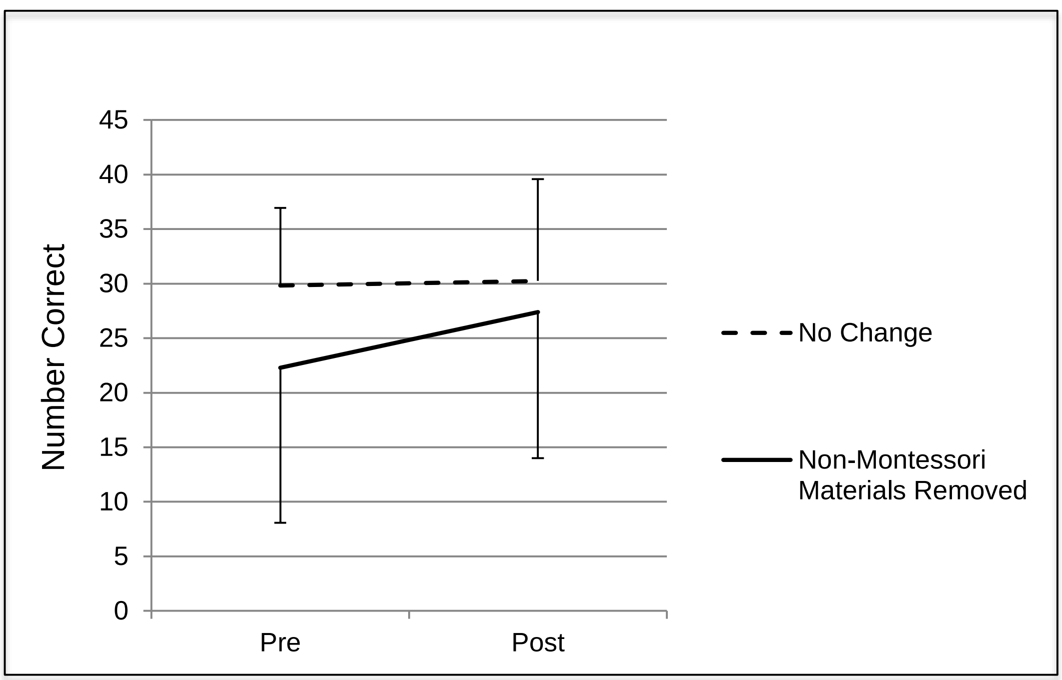

Figure 2. Change in HTKS scores from pretest to posttest. *Y*-axis represents number correct; error bars represent *SD*s.

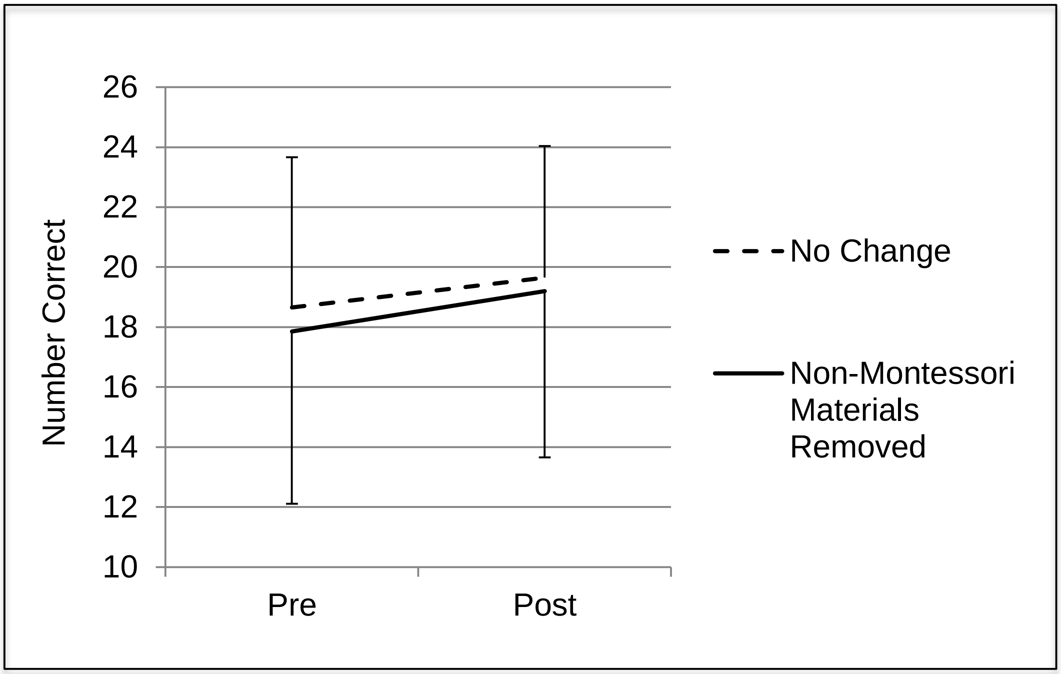

Figure 3. Change in Applied Problems scores from pretest to posttest. *Y*-axis represents number correct; error bars represent *SD*s.

On the Picture Vocabulary subtest, theory of mind scale, and the SPST-R, there was no difference in the degree of change between children in the two types of classrooms across the 4 months.

Discussion

In a prior study, children in classrooms in which children only had access to—and therefore virtually always used—Montessori materials advanced significantly more across the school year than did children in Montessori classrooms that supplemented their offerings with non-Montessori materials and in which children were using those non-Montessori materials roughly half the time (Lillard, 2012). The Montessori materials could have caused this difference, or they could have been a proxy for something else that actually caused the difference, ranging from teachers having different standards to parents' preferences for different classrooms (to the degree that parents specifically might have chosen a particular class). The best way to determine if the materials really matter is through an experiment.

A small-scale experiment was conducted to examine whether removing non-Montessori materials makes a difference on its own. Although the intervention lasted only 4 months, children in classrooms from which non-Montessori materials were removed advanced significantly more on two of six measures and slightly but nonsignificantly more on a third measure. These results are discussed in turn. As in prior research (Lillard, 2012), when supplementary materials were present, children used them a reasonable amount of the time; use of Montessori materials sharply increased (from 34% to 58% of the time) after the supplementary materials were removed.

First, although children in the unchanged classroom scored higher at both time points on the HTKS, a test of executive function, they did not improve at all on this measure across the 4 months, despite ample room for improvement. Children in the changed classrooms, by contrast, advanced a great deal over the 4 months. How might removing non-Montessori materials have influenced children's performance on this task? The task requires children to hold rules in mind and to inhibit the prepotent response of touching the location that the experimenter's command, taken literally, told them to touch. Children, in addition, had to plan and execute the opposite response. One possible explanation for why children in the changed classrooms improved more on this task is that Montessori materials incorporate analogous demands to a greater degree than supplementary materials do. For instance, in several Sensorial exercises, children are asked to hold one sensory experience (the pitch of a Musical Bell or the length of a Red Rod) in mind as they cross the room to get its match (in the case of a Bell) or the Rod that is closest in length to the one they have. This task seems to challenge working memory in a way that, for example, putting together a commercial puzzle may not. In addition, all the Montessori materials are used according to specific steps, and children must keep these steps in mind as they plan and execute each action. In a Practical Life activity, for example, there is an order in which a child gathers the materials, lays them out for use, uses them, and finally puts them away. Perhaps Montessori teachers do not present supplementary materials with this same degree of precision. Hence, one possible reason for the rise in executive function when non-Montessori materials were removed concerns the Montessori materials themselves and how they are presented and used.

The second possible explanation we discuss is actually a by-product of the materials, and it concerns depth of concentration. Dr. Montessori repeatedly described seeing a child become transfixed by the wooden cylinders, such that even when others sang and danced around her, and even when her chair was lifted, her concentration was unbroken (Montessori, 1956, 1966, 1998). Dr. Montessori went on to observe this phenomenon in other children, with other materials. This deep concentration is something that Montessori teachers also observe today. Furthermore, Dr. Montessori claimed—and teachers today observe—that, after children had experienced this deep concentration, their personalities "normalized," and they became kinder and more compliant, made better choices, and had better self-control. Perhaps after the non-Montessori materials were removed and children had fewer options than to choose Montessori materials, they were more likely to have these concentration experiences and subsequent improvements in self-control, leading to higher scores on this task.

The advance in Letter−Word performance seems most likely to be related to the use of specific language materials. When commercial puzzles, games, crafts, projects, and other non-Montessori materials were no longer available, perhaps children went on to use the Language materials more, leading directly to this advance. Indeed, in an earlier, unpublished study involving nine Montessori classrooms, we found that the percentage of children engaged with Language materials in each Montessori classroom predicted the mean level of advance in Letter−Word performance in that classroom. Working with Language materials, like the Sandpaper Letters and the Moveable Alphabet, translates directly into doing well on the Letter−Word task, which requires children to read letters (*k* and *b*, for example) and then increasingly complex words.

This same factor may have led to the small improvement seen in the Applied Problems test, which begins with simple addition and subtraction and then moves to word problems, coins, and clock faces. With the Applied Problems test, the mapping from the materials to the test is less clear than for Letter−Word. The letter *p* on a Sandpaper Letter looks just like the *p* in the Woodcock–Johnson test, whereas the Applied Problems test has children count crayons and balloons rather than wooden spindles, red counters, and glass beads. Still, lack of non-Montessori materials may have led some children to engage more with Montessori Math materials than they otherwise might have, leading to this small increase.

Children did not advance more on the Picture Vocabulary subscale or on the two social tests (theory of mind and SPST-R). Although many Montessori materials teach nomenclature, the words taught are unlikely to align with the specific Woodcock–Johnson Picture Vocabulary test items. Vocabulary growth also accrues in conversation and reading, including books at circle time (Blachowicz, Fisher, Ogle, & Wattes-Taffe, 2006), but these activities are not likely to be influenced by the presence of materials. It is also possible that the Montessori materials would lead to better vocabulary over time, but not in 4 months.

The presence of non-Montessori materials might have little influence on social interaction in a Montessori classroom, especially if there was still only one of most materials, as was the case in these classrooms. Having only one copy of each material, regardless of its being a Montessori material or something else, might lead children to learn effective social problem-solving strategies to induce sharing behavior. Second, the degree of social interaction probably is not influenced by the amount of non-Montessori material, explaining the lack of difference on the theory of mind test. The fact that an earlier study did see classic–supplemented differences on tests of social cognition and behavior may suggest that a longer time period is needed to see differences or that the materials served as a proxy for some other classroom differences that led to different performance on the social tests. Another factor to consider is that in Lillard (2012) the children in classic Montessori classrooms used Montessori materials almost 100% of the time, whereas in the non-Montessori materials removed classrooms here, they used them only 58% of the time.

Limitations and Future Directions

Although removing non-Montessori materials did appear to influence how much children changed in the subsequent 4 months, which is consistent with Lillard (2012), the study has some clear weaknesses. First, the study was small: Only 52 children, from just three classrooms at one school, were studied, and the study was of only 4 months' duration. A larger sample would be especially useful. It is notable that the age ranges of children were similar across the different groups; the development of children of different ages is likely influenced differently by the presence or absence of different Montessori materials. Using only one school could be seen as a strength, as it means the children in the two samples were demographically similar. However, it is also possible that the individual teachers in the classrooms, rather than the change in materials, were responsible for the different levels of gain. Against this theory is the fact that children across the two types of classrooms scored the same at pretest on all but one measure. Finally, the short time frame of the study is a limitation; seeing children's trajectories over a whole school year, or several years, would be more revealing. Still, the results of this small study do suggest, using an experimental design, that children may be better served in Montessori classrooms that use only Montessori materials and that do not supplement that set of materials with commercially available toys.

Conclusions

Provision of materials is one important aspect of Montessori classrooms. Maria Montessori was very clear about this.

> The material should be limited in quantity. Properly understood, this principle is clear and logical. A normal child does not need stimuli to awaken him or put him in contact with the material world. He needs rather to bring order into the chaos created in his mind by the host of sensations coming to him from the outside world. [The child is] an ardent explorer of a world that is new to him. And what he needs, as an explorer, is a road (that is something which is straight and limited) which can lead him to his goal and keep him from wandering aimlessly about. He then passionately attaches himself to those things, limited and direct in scope, which bring order in to the chaos that has been created within him; and with this order, they provide light for his exploring mind and a guide for his researches. The explorer who was at first abandoned to himself then becomes an enlightened man who makes new discoveries at every step and advances with the strength which he receives from his inner satisfaction.
>
> Evidence of this kind should certainly modify the notion, still held by many, that a child is helped in proportion to the number of educational objects that are placed at his disposal. It is common, but false, belief that the child who has the most toys, the most help, should also be the most developed. Instead of that, the confused multitude of

objects with which he is surrounded only aggravate the chaos of his mind (Montessori, 1967, pp. 104–105).

The materials Maria Montessori and her collaborators created were specifically designed to "bring order into the chaos" of the child's mind (p. 105), for example by abstracting the qualities of the sensory world, and engaging the child with specific routines that take care of and beautify the environment. The importance of the materials is an aspect of Montessori education that teachers appear too often to forget, as they often supplement the basic set of Montessori Primary materials with commercially available toys. The results of this small study, taken together with Lillard (2012), suggest their supplementation is a mistake and that children's development is helped when only the Montessori materials are made available.

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Examining a Montessori Adolescent Program through a Self-Determination Theory Lens: A Study of the Lived Experiences of Adolescents

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***Keywords**: middle level education, Montessori education, Montessori adolescent program, motivation, self-determination theory, narrative analysis, analysis of narratives*

Abstract. This study examined the influence of enrollment in a Montessori adolescent program on the development of self-determination. The study focused on seventh-grade students. Student feelings of self-determination were recorded through three cycles of interviews throughout the year to capture the change, if any, in feelings of self-determination. Bounded by self-determination and student-voice theory, this research was designed to give voice to students, add to the discourse on middle-school reform, and provide the perspective of the student.

Based on the analysis of narratives, the major themes indicated the feelings of autonomy, competence, and relatedness that were most prevalent. The study suggests ways in which Montessori adolescent programs support students and in which other middle-level schools can support students.

Literature Review

The design of the Montessori adolescent program was based on the notes and transcripts from a lecture series in which Maria Montessori coined the term *erdkinder*—child of the land. She used the term to describe the child in the third plane of development defined as ages 12 to 18. She also used *erdkinder* to refer to the adolescent learning environment (Montessori, 1967). She believed that the upheaval of this stage was a special time during which the spiritual embryo of the child could awaken. The adolescent program was a place to nurture older children's intellectual, psychological, and emotional development, where children could be liberated through education within a community of caring adults and peers (Montessori, 1967). Choice, working toward mastery, and building community—all hallmarks of Montessori philosophy and methodology—are the foundation upon which autonomy, competence, and relatedness are developed.

Autonomy, competence, and relatedness are the three constructs of self-determination theory (SDT), a subtheory of human motivation developed in 1985 by Deci and Ryan. This work defined self-determination as the feeling of control over one's destiny. International studies showed that when the needs to develop autonomy, competence, and relatedness were supported, individuals felt in control of their destiny, motivating them to achieve their goals.

Supports for these needs are embedded in the adolescent program as described by Montessori (Montessori, 1964, 1972b, 1973). The present study sought to capture the experiences of seventh-grade

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students in their first year of a Montessori adolescent program to determine if enrollment in the program affected the development of self-determination. Six students were interviewed at the beginning, middle, and end of their seventh-grade year to gauge the change, if any, in their feelings of self-determination. The question that guided this study was: What do seventh-grade students say that points toward feelings of increased self-determination that may be attributed to their enrollment in a Montessori adolescent program?

Development of the Montessori Adolescent Program

After her first successes with preschool-aged children, Montessori continued to write and to develop programs and schools throughout the world until her death in 1952 (Standing, 1988). Although she wrote speeches and developed theories about the specific needs of the adolescent, she did not design the *erdkinder*. Rather, the work of others—influenced by Montessori's philosophy—ultimately developed the adolescent program. In particular, Coe (1988) described and analyzed the effectiveness of the adolescent learning community Coe developed. She drew from Montessori's writings as well as Kohlberg's theory of moral development and Erikson's stages of development (Erickson, 1950; Kohlberg, 1981; Montessori, 1967).

Coe (1996) detailed the strategies and practices that enabled teachers to form communities within their school environments. She reflected on the challenges faced by adolescents as they began to define themselves not only in small peer groups, but also within a larger school community. The push and pull both toward and away from peers and family is unique to adolescence. (Montessori, 1967). As a result, although the adolescent program contains the same hallmarks as learning environments created for younger children, the scopes of these concepts are broadened when the notion of community expands from school to neighborhood, city, government, and world.

Self-Determination Theory (SDT)

Montessori's writings about her method and the *erdkinder* include practices and structures that support the intellectual, psychological, and emotional development of children. These structures align with the basic needs defined in SDT. SDT posits that humans seek out and align themselves with situations that will enable them to meet three universal needs: autonomy, competence, and relatedness (Deci & Ryan, 2002). The Montessori practice of allowing students to choose their work is a support for autonomy. Allowing students to work toward mastery is a support for competence. Relatedness is supported by the inclusion of peace education and conflict resolution in the *erdkinder* curriculum.

Domestic and international research shows a strong positive correlation between self-determination and student achievement (Ryan & Deci, 2000b; Jang, Reeve, Ryan, & Kim, 2009; Shih, 2008). The Carnegie Council on Adolescent Development's (CCAD) 1989 report, *Turning Points: Preparing American Youth for the 21st Century*, advised middle-level education reforms, including small communities of learning led by caring, respectful adults; rigorous academics tailored to students' specific needs. Further, an environment that supports the development of self-determination creates intrinsic motivation, well-being, and a unified sense of self (Ryan & Deci, 2002). Conversely, students in settings in which these basic needs are not supported are less engaged and less motivated to achieve (Niemiec & Ryan, 2009). Research in education and psychology, as well as Montessori's writings, suggest ways to create environments that can support adolescent development. Examination of educational settings through the lens of SDT has shown that teachers and administrators can encourage the development of these constructs. In the following sections, each construct will be discussed in depth.

Autonomy. Autonomy is created when individuals are the locus of control for their actions. The locus of control determines the level of motivation, from amotivation to intrinsic. Individuals can act through external pressure or for extrinsic rewards. When pressure is external, the locus of control is outside of the individual, and performance in these circumstances tends to be short-lived. Conversely, as the locus of control is internalized, long-lasting performance, competence, and the drive to continue toward mastery increase. In addition, individuals can be extrinsically motivated if autonomy and mastery are supported by the extrinsic rewards. For example, students who may not be drawn to the study of organic chemistry can be motivated to earn the extrinsic reward of grades because they want to and have chosen to master chemistry concepts to gain acceptance into medical school (Deci & Ryan, 2000).

Autonomy supports are a hallmark of Montessori methodology. Montessori spoke of choice, challenging teachers to allow students to choose work. In this way, the teacher encourages students to build their own intellect: “Thus here again liberty, the sole meaning will lead to the maximum development of character, in intelligence, and sentiment; and will give to us, the educators, peace and the possibility of contemplating the miracle of growth” (Montessori, 1964, p. 6). Adolescents’ need for choice is highlighted in *This We Believe,* in which the Association for Middle Level Education [AMLE] suggests “multiple learning and teaching approaches that respond to their [students’] diversity” (2000, p. 7). The use of multiple learning approaches allows students to choose how and with what modality they construct their knowledge and demonstrate their understanding.

Competence. Satisfaction of the need for competence is supported by structures and practices that allow people to demonstrate their abilities. People who perceive themselves as competent are confident in their abilities to surmount obstacles and challenges. They feel capable, they challenge themselves, and they are motivated to acquire and practice the skills needed to reach their goals (Ryan & Deci, 2000a). Results of international studies of competence suggest a link between perceived competence and student achievement (Jang et al., 2009; Miserandino, 1996). One study also linked competence to feelings of well-being (Sheldon et al., 2009).

The subjects of the aforementioned studies (Jang et al., 2009; Miserandino, 1996) were adolescents, and study results echo Montessori’s recommendation that teachers support students in the quest for skill attainment. Her instruction to create materials for auto-education, as well as her observation that children thrive in environments in which they are allowed to work to mastery uninterrupted, instilled in students that they had the power to create their own meaning and intellect (Montessori, 1964). While her early work described this process for preschool-aged children, Montessori included these same recommendations for the middle-school program. AMLE’s call for a culture that includes “students and teachers engaged in active learning” (2000, p. 15) also includes students creating meaning through teaching, peer tutoring, and active engagement in school governance. These practices foster a sense of ability to affect their school setting.

Relatedness. Practices and structures that foster caring relationships support the fulfillment of the need for connection (Deci & Ryan, 2000). A hallmark of adolescent development is the creation of deep connections among peers. Adolescence is a time when students define themselves through not only academic successes but also social ones (Elkind, 1994). Relatedness is experienced as a feeling of being safe within both individual and community relationships. Perceived relatedness in adolescents has been shown to encourage well-being and academic achievement (Jang et al., 2009; Rathunde & Csikszentmihalyi, 2005a). In addition, students who expressed that their need for relatedness was satisfied were more likely to connect with their school culture (Niemiec & Ryan, 2009; Rathunde & Csikszentmihalyi, 2005b).

This connection to peers is important as students in the adolescent program begin to work outside of the school community. Montessori believed that children had both innate curiosity and innate goodness. She believed that children, provided with examples of goodwill and direction toward understanding, were the world’s only hope for peace. Teachers were directed to notice when children became aware of peer reactions to their behavior and to provide examples of kindness and understanding (Montessori, 1972a). Within this environment of understanding and caring, the spiritual embryo of the child was brought into peaceful existence. Supports for relatedness—including a caring adult who advocates for students, a caring and safe environment, and cultivation of relationships—are suggested in the CCAD (1989) and AMLE (2000) documents. As adolescents learn their place in the greater community, they learn the skills needed to positively affect their environment.

Student Voice and SDT

Student voice—a theoretical framework—creates an intimate portrait of the lived experience of the most important stakeholders in education. Student-voice researchers advocate that students be given the opportunity to work alongside researchers, educational leaders, and policy makers. Rather than be the objects acted upon by the system, students are empowered to shape and determine their own destinies within it. The use of qualitative methods thus captures the lived experience of those most affected by educational policies and practices. Inclusion of this framework in this study gives voice to the adolescent in a Montessori middle school in a way that examination of achievement data and surveys cannot.

As with other theoretical frameworks, there are both advantages and disadvantages to the use of student-voice research methods. Student voice is a lens through which researchers have been able to view the effectiveness of reforms (Fielding, 2001; Kruse, 2000), the reasons for disengagement from school culture and apathy toward academic achievement (Daniels & Arapostathis, 2005; Kroeger et al., 2004), and youth development (Mitra, 2004). The difficulties lie in (a) proclaiming that the captured voices are representative and generalizable to the overall population of adolescents, (b) the deletion of the key components of transcripts by researchers due to bias, (c) the exclusion of the experiences of those who do not or will not speak, and (d) the reinforcement of current power dynamics between teachers and students (Cook-Sather, 2006; Fielding, 2004).

SDT researchers have used extant data, achievement data, survey results, and experimental practices to highlight the importance of autonomy, competence, and relatedness to adolescent development and achievement (Vansteenkiste, Lens, & Deci, 2006; Ryan & Shim, 2008). Student-voice research, in contrast, is primarily concerned with illuminating the lived experience of students. What students say and do become data that researchers can analyze to gather themes related to development and the effect that construct supportive practices have on students' feelings of well-being. Findings from student interviews corroborate the data gathered from quantitative methods. Adolescents crave the constructs of autonomy, competence, and relatedness. Youth in several studies reported that when teachers create learning environments that support autonomy and competence (Kroeger et al., 2004; Mitra, 2004) or relatedness (Daniels, 2011; Daniels & Arapostathis, 2005; Kroeger et al., 2004), they feel more motivated to complete work and tasks that they would not otherwise be intrinsically motivated to complete.

The present study sought to capture the experiences of seventh-grade students as they acclimated to a Montessori adolescent program: How would a learning environment designed to support students' development of autonomy, competence, and relatedness affect their sense of self-determination during their seventh-grade year?

Methods

The current study was conducted at a charter school in a suburban city in southwestern California. The school site served 450 students in kindergarten through eighth grade. The study focused on a small subset of the student population: students enrolled in the Montessori adolescent program, which serves seventh- and eighth-grade students in three mixed-age classrooms. At the time of the study, the program was in its third year of implementation, and 92 students were enrolled. The three teachers working in the program held both the California Multiple-Subject Credential and the Secondary I/II credential provided by the American Montessori Society.

Purposeful Sampling

Participant-selection variant of an explanatory sequential design. The use of this methodology is appropriate for the study because it allowed for the purposeful selection of participants for the second qualitative phase. Purposeful selection ensured that the finished analysis of narrative contained a representative sampling of the students' voices at the research site. The research question, as well as the student-voice framework, calls for emphasis on the qualitative methods phase. The use of quantitative data for participant selection allows for the deeper study of subjects who exhibit varying levels of self-determination (Creswell & Plano-Clark, 2007).

Reasoning for choice of initial sampling group. All seventh-grade students attending the research site's Montessori adolescent program were invited to participate in the study. The study focused on seventh grade because it marks the first year in the adolescent program. All students in the seventh-grade sample were experiencing a transition into the adolescent program. Of the total population of 48 seventh-grade students, 11 students completed the consent forms.

Instrument: BNSW-S for Adolescents. Students who returned a consent form completed a modified version of the Basic Needs Satisfaction Work Scale-Student (BNSW-S) for adolescents. This version of the BNSW-S was used to measure SDT constructs in adolescents transitioning to high school (Gillison, Standage, & Skevington, 2008).

Validation of BNSW-S for Adolescents. Gillison et al. (2008) modified questions from the BNSW-S to include educational-setting terminology that adolescents would understand. For example, the statement "When I'm at work, I have to do what I'm told" was changed to "When I'm at school, I have to do what I'm told." Students answered the survey using a 7-point Likert scale ranging from *not true at all* (1) to *very true* (7). In addition, students of the same age who were not in the sample group also took the survey. When these students were asked if they understood the questions on the scale, they indicated that they understood the vocabulary and did not need further explanation of terms. (Gillison et al., 2008). Based on these results, I requested the modified version of the BNSW-S for Adolescents from Gillison, who sent me all forms required to administer the survey.

Purposeful sampling strategy. The 11 students who submitted consent forms were invited to complete the survey. I met with this group in the morning at a time that was convenient for both teachers and students. The survey was administered in a pencil-and-paper format. I stayed at the back of the room to answer any questions. All students completed the survey within 15 minutes. None of the students asked for clarification during administration of the survey. BNSW-S for Adolescents data from the 11 students were coded and entered into IBM SPSS Statistics 20. Bands for low, medium, and high self-determination (Gillison et al., 2008) were used to determine the levels of self-determination in the student sample

Analysis of quantitative data. Scores were categorized into bands of low, medium, and high self-determination. Descriptive analysis was conducted to identify groups of students based on their perceived overall feelings of autonomy, competence, and relatedness. Demographic data collected in the original data were used to identify one male and one female student from each band, bringing the total sample size for the qualitative phase to six. Results from descriptive analysis of the surveys are presented in Table 1 and Figure 1.

The intent of the study was to gather qualitative data from students with low, medium, and high self-determination based on the data from the BNSW-S. A mean score of 4.9 showed that the 11 seventh-grade students who took the BNSW-S had medium-to-high self-determination scores. None of the students who completed the scale measured low in self-determination. Although my sample did not include students with low measured self-determination, I decided the importance of capturing the voices of these students would still add to the existing literature on the adolescent-lived experience and provide insight into practical implications.

While the data fell within the medium-to-high self-determination range, three bands of data were discovered in the sample: below-the-expected median, at-the-expected median, and above-the-expected median. The original design of the study called for the identification of six students: two students from each band of low, medium, and high self-determination. Because the sample did not contain students with low self-determination, two students were chosen from the bands that were identified. In keeping with the original study design, demographic data were used to identify one male and one female student from the below-the-expected median, at-the-expected median, and above-the-expected median bands. All students in the at-the-expected-median band were female; thus, this group had two female representatives. As a result, a total of six students (two males and four females) were invited to participate in the qualitative phase of the study. Table 2 details the demographic data of the invited participants.

Table 1

Table of Mean Self-Determination and Total Self-Determination (SD)

Participant	Mean SD	Total SD
	3.1	75
G1	3.9	93
M4	4.2	100
G9	4.4	106
G4	4.5	108
G2	5.2	125
G11	5.3	129
G8	5.5	131
M3	5.8	138
G7	5.8	140
G5	6.4	154

Note. Mean SD and total SD used to choose participants for the qualitative phase. Two subjects below the expected median, at the expected median, and above the expected median were chosen. When possible, one male and one female were chosen from each band.

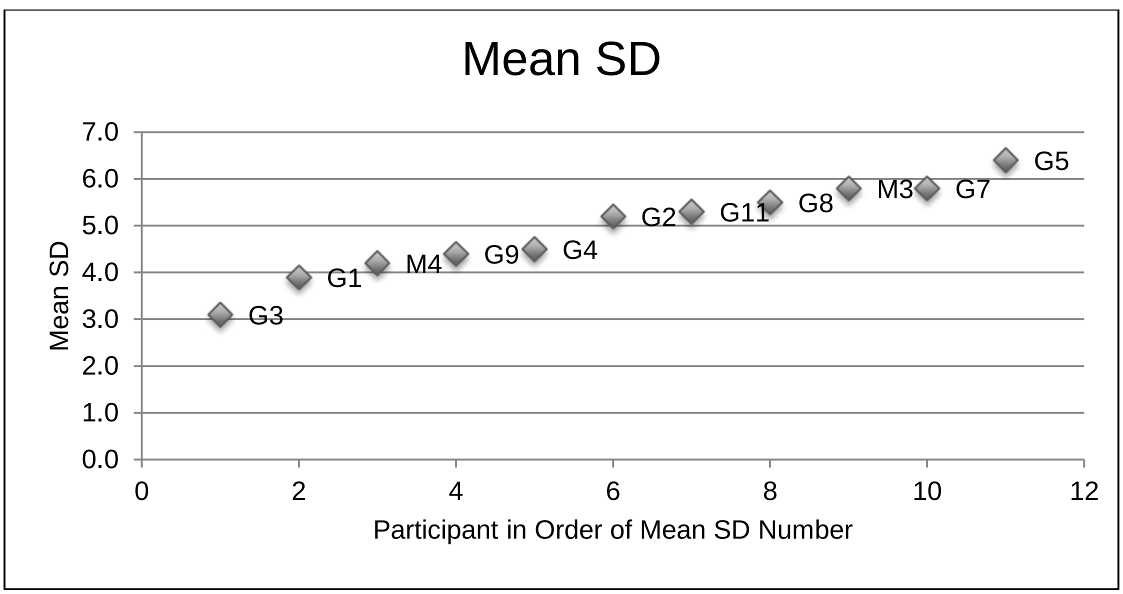

Figure 1. Graph of mean self-determination (SD) used to choose participants.

Instrument: semistructured interview. Accounts of students' lived experiences over a 7-month period were collected through semistructured interviews. The interview protocol and questions were intentionally sparse to allow for the conceptual transformation of interviewer and interviewee to listener and narrator (Chase, 2005). The questions were designed to be both specific and open ended. For example, to measure feelings of autonomy, I asked students if they felt they had choice and freedom in the work they do at school. To avoid questions that could imply specific answers, I paid close attention to verbiage and word choice. The protocol included nine questions designed to gather background information as well as measure feelings of autonomy, competence, and relatedness. Specific phrases such as *Tell me more* and *Please describe that in more detail* were used to draw out more information. Due to the small sample size for the qualitative phase, I conducted all of the interviews.

Table 2

Demographic Information for Qualitative Phase Participants

SD Band	Participant	Sex	Years in Montessori
Below the Expected Median	G3	Female	1
Below the Expected Median	M4	Male	2
At the Expected Median	G2	Female	1
At the Expected Median	G11	Female	1
Above the Expected Median	G5	Female	6
Above the Expected Median	M3	Male	1

Note. Students indicated how many years they had attended a Montessori school. In *Years in Montessori,* a 1 indicates that students were in their first year of Montessori education.

Validation of interview protocol. In the spring, prior to the study, interviews were conducted to gauge whether the questions were understandable to seventh- and eighth-grade students, as well as whether the collected answers reflected the type of response data that would address the research questions. Student responses indicated that not only did students understand the questions, but also that these questions were valid for collecting data that addressed the research questions.

Narrative analysis and analysis of narratives. Analysis of qualitative data was conducted through both narrative analysis and analysis of narrative methods. Interviews were professionally transcribed and checked against audio to validate accuracy. Narrative analyses of each subject's interviews were examined for themes. I conducted in vivo coding, which identified phrases and words that pointed toward themes that were generalizable to the individual narrative. This phase differed from the analysis of narratives phase, in that findings were gleaned from individual narratives. During the analysis-of-narratives phase, phrases and words were identified across narratives based on the phrases and words used in the in vivo coding that was conducted in narrative analysis, giving a general set of themes for all participants across all interview cycles.

Analysis of qualitative data: narrative analysis. Students were assigned a code corresponding to their gender and the order in which they submitted their consent form. The chosen students were referred to by their coded names (e.g., G3 was the third girl who submitted her consent form) throughout the interview cycles. Each participant was interviewed separately at selected times during the school day. Teachers were consulted to determine the times of the day that would be least disruptive to student productivity.

I recorded the audio from each interview. Audio recordings were professionally transcribed, and transcriptions were checked for accuracy. In vivo coding was used to develop themes. This process was repeated for each cycle of interviews, which occurred in November, February, and May. I compiled codes from each participant's interviews to gather a narrative of the student's experience. Although the intent was to collect narratives from the students throughout their seventh-grade year and note the development of feelings of self-determination, examination of in vivo codes revealed that students' overall feelings of autonomy, competence, and relatedness did not change. Students reported feelings of autonomy, competence, and relatedness in each cycle of interviews.

Analysis of qualitative data: analysis of narratives. After completion of narrative analysis, the in vivo codes were grouped into themes found throughout the narratives of all participants for all interview cycles (Table 3). These themes were entered manually into mind-mapping software to produce graphic representations of data. This analysis produced a rich, multilayered approach to the codes and themes identified through the entire body of narrative text. A combination of in vivo coding and cluster coding was used to group similar words, such as the clusters for choose–choice–chose and free–freedom. Groupings of codes were developed into themes that were categorized as major or minor. The data revealed major themes that represented a majority or all of the students in the qualitative phase.

Table 3

Themes Identified Through In Vivo Coding

SDT Component	Themes Identified	Utterances: Students
Autonomy	Choose Type of Work	48:6
	Choose Order of Tasks	24:6
	Choose Clothing	9:1
	Free to Express Yourself	3:1
	Choose with Whom to Work	3:3
	Choose Where to Work	2:2
	Choose to Retake Tests	1:1
Competence	Scared at First…Now I Can	18:6
	Organize Time	10:6
	More Social Confidence	5:3
	Capability to Do Well in High School	3:3
	First Things First	1:1
	Perseverance	1:1
	Think Win-Win	1:1
Relatedness	Teacher Care: Help Me Stay on Top of Things	30:6
	Student Care: Community Meeting	11:3
	Student Care: Nice to Me	6:5
	Student Care: Academic Help	5:3
	Teacher Care: Offer Fun Activities	3:3
	Teacher Care: Conflict Resolution	3:2
	Student Care: Not Bullying	3:1
	Teacher Care: Respect Opinions	2:2
	Staff Care: Make Sure…	2:1
	Student Care: Some Students Care	2:1
	Teacher Care: Provide Challenging Work	2:1
	Staff Care: Help When Hurt	1:1
	Staff Care: Take Care of Bad Language	1:1
	Staff Care: Take Ideas	1:1
	Student Care: Don't Care Who I Hang Out With	1:1
	Teacher Care: Good Connection	1:1

Note. Themes identified through analysis of narratives. Themes are presented by descending number of utterances represented in each theme. Ratios represent number of utterances to number of students.

Results

Major Themes Within the SDT Construct of Autonomy

All students used words or phrases related to choice throughout the narratives. Participants included choice in their answers regarding feelings about the middle-school program, differences between the middle-school program and their last school environment, and feelings about choice and freedom in their work at school. Figure 2 illustrates the way in which in vivo codes were grouped into types of choice in a mind-map graphic. This theme incorporated in vivo codes representing 48 utterances related to *Choose Type of Work*. Furthermore, Choose Type of Work was mentioned by all students. The number of times Choose Type of Work was mentioned, coupled with the fact that all students mentioned it, illustrates that choosing work was very important to all students in the sample.

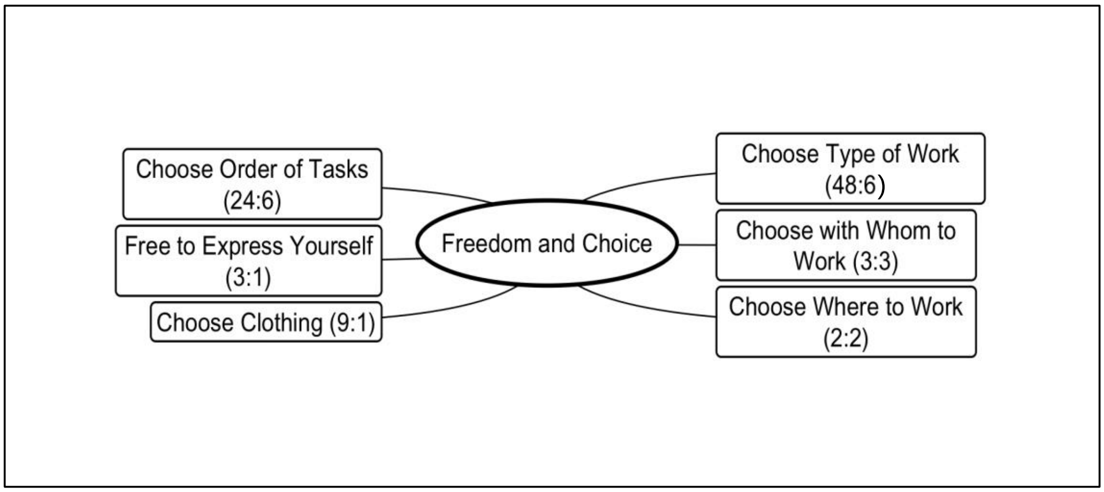

Figure 2. Freedom and choice mind map. In vivo codes grouped into themes. Brackets denote number of times students mentioned type of choice: number of students who mentioned type of choice

The *Choose Order of Tasks* theme incorporated in vivo codes representing 24 utterances. Every participant mentioned Choose Order of Tasks. The number of times Choose Order of Tasks was mentioned, coupled with the fact that all students mentioned it, is important.

Major Themes Within the SDT Construct of Competence

Figure 3 uses a mind-map graphic to illustrate the themes identified through analysis of narratives for the SDT component of competence. One major theme emerged in all three cycles and was mentioned by all group members. Participants mentioned that, at the beginning of the school year, they had had negative feelings about their ability to finish all assignments and do well. Although students reported emotions about academic work at the beginning of the year—fear, anxiety, and worry—at the time of the first cycle of interviews conducted in November, all participants noted that they felt confident that they could, in the words of student G11, "get all the work done." Positive feelings about the ability to complete work occurred as early as the first cycle of interviews. Belief in the ability to complete work was mentioned a total of 18 times throughout the complete narratives of all participants over all three cycles of interviews.

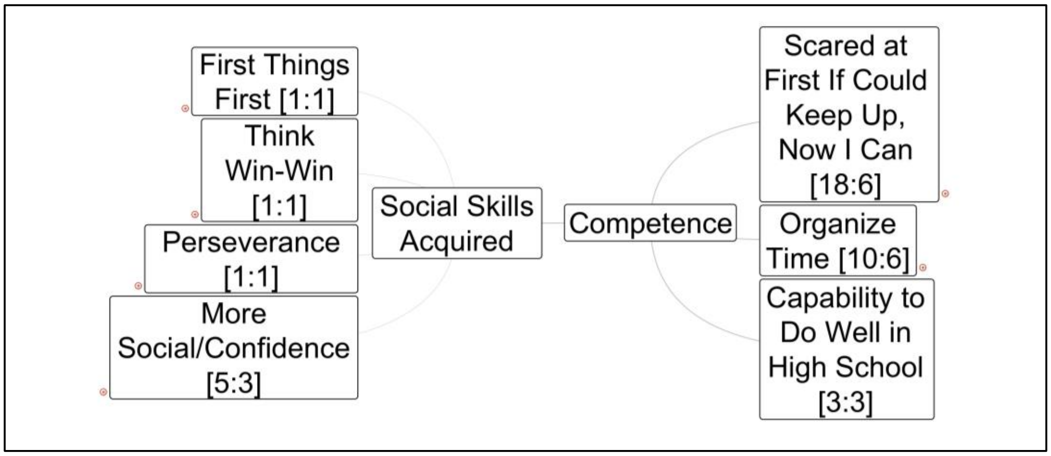

Figure 3. Skills mind map. In vivo codes grouped into themes. Brackets denote number of times students mentioned type of skill: number of students who mentioned type of skill.

Major Themes Within the SDT Construct of Relatedness

Relatedness was measured by utterances of feeling connected and cared for within the adolescent program. Caring by teachers, staff, and students was a recurring theme throughout all interviews. Figure 4 contains a mind map that illustrates the ways in which students felt people at the school cared for them.

A significant number of teacher-care actions emerged from the narratives. Teachers showed they cared in 13 distinct ways. The most prevalent theme for teachers was *Helping Me Stay on Top of Things*, which included actions such as redirecting off-task behavior, helping with task organization and planning, creating homework contracts, and issuing notes to parents about missing work (*orange slips*). When I asked students about homework contracts and orange slips, students responded that neither action was punitive. In fact, a few participants mentioned choosing homework and choosing to receive an orange slip so that they could spread work out over the weeknights or weekends. The theme Helping Me Stay on Top of Things represented 30 utterances by all six participants.

Discussion

Implications for Educators of Middle School Students

Personalized learning. Reform at all levels, spearheaded by the adoption in 45 states of the Common Core State Standards (CCSS), focuses on deep learning that can be fostered only through empowered learning. The CCSS call for a personalized learning approach that gives students choice in work and shows them how to demonstrate mastery (NETP, 2010). This learning strategy is a foundational characteristic of Montessori methodology and practice. Furthermore, personalization supports the development of autonomy. As noted in the findings, the theme Choose Type of Work was important to student satisfaction in the Montessori adolescent program. Student G3 mentioned that her interest in writing led her to choose writing assignments, to write more for each assignment, and to write the text for group assignments. The voices of the participants in this study add to what has been quantified in international studies.

Support for personalized learning is further corroborated by domestic and international studies. Studies of Montessori practice (Dohrmann, Nishida, Gartner, Lipsky, & Grimm, 2007; Hanson, 2009; Hobbs, 2008; McCladdie, 2006; Peng, 2009) included the same learner-centered approaches, such as differentiated instruction and auto-education, cited in general education studies (Weinberger & McCombs, 2003). These findings are also found in SDT literature, pointing to a possible positive correlation between autonomy supports and student achievement (Chirkov, 2009; Chirkov & Ryan, 2001; Niemiec, et al., 2006; Shih, 2008; Soenens & Vansteenkiste, 2005).

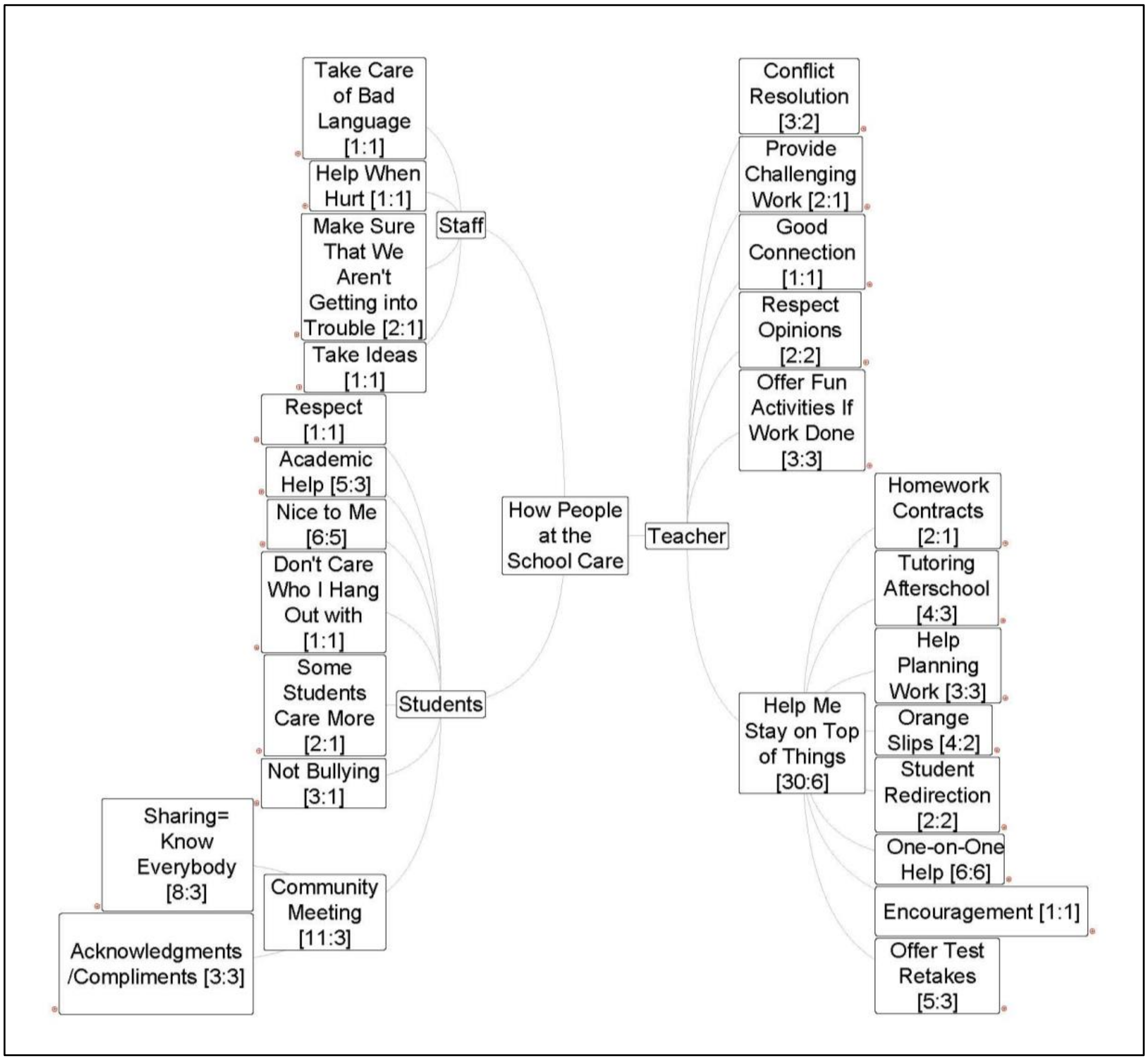

Figure 4. How people care mind map. In vivo codes grouped into themes. Brackets denote number of times students mentioned type of care: number of students who mentioned type of care.

Community. Participants in this study mentioned the various ways in which caring individuals supported them. Students freely used the term *community* and expressed feeling that they were cared for by students, teachers, and staff. Domestic and international studies suggest a positive correlation between increased relatedness and student achievement (Dee, 2004; Goddard, Tschannen-Moran, & Hoy, 2001; Goddard, Salloum, & Berebitsky, 2009; Jang et al., 2009; Musial, 1986; Roessingh, 2006; Sahlberg, 2007; Wentzel, 1991). Montessori's writings, as well as articles written by current Montessorians, detail and illustrate the importance of building relational trust to create an authentic Montessori learning environment (Coe, 1996; Enright, Schaefer, Schaefer, & Schaefer, 2008; Gillespie, 1994; Montessori, 1973; Rule & Kyle, 2009). Teacher care was felt strongest when teachers supported learning through one-on-one help, creation of homework contracts, afterschool tutoring, and test retakes. Student M4 stated,

> It makes me feel like they care about us achieving all our work and getting it done because on [sic] other school that I went to they didn't seem like they cared whether we got all our work done or not. If we didn't have it done, they would automatically give us a grade.

This thought was echoed in similar ways by students G5, M3, and G2. They had wanted to succeed in their previous learning environments; however, they had not been given the help to do so, hampering their ability to do well and feel good about their work. Making time in the work period for individual help, tutoring, and test retakes showed teacher care. These practices can occur when teachers have both the will to provide these structures and the support to do so. These small changes could have a big impact on student motivation and achievement.

Personalized learning practices require teachers to alter their teaching practices and classroom management. Teacher care requires that teachers invest time in better understanding their students. These paradigm shifts can occur only in environments that are risk supportive.

Implications for Educational Leaders

Montessori methodology and practice include supports for autonomy, competence, and relatedness. Domestic and international studies indicate a positive correlation between self-determination supports and increased student achievement. Students in this study consistently felt they had freedom and choice and that they were cared for by teachers, staff, and other students. Their voices captured in this study point toward a positive feeling of self-determination.

The findings in this study indicate the practices and program characteristics that students most value. Teacher practices included reteaching, personalized learning, test retakes, helping students create plans to catch up on work or skills, and afterschool tutoring. These same practices are described in foundational material that detail middle-level reform (CCAD, 1989; AMLE, 2000) and recent reform (NETP, 2010). Although these practices are common features in Montessori learning environments, they do not require that teachers complete Montessori training.

Practices listed in the previous section require two things: the willingness of teachers to shift their classrooms from teacher centered to student centered, and support from school administration. This finding is echoed in another study of trust and improvement in schools, which found that, in schools that had successfully implemented reforms, teachers consistently cited trustworthy faculty relationships as a principal component of these successes. (Louis, 2007). Administrative support can come in the form of providing staff development and training, including collaboration time, and offering release time for teachers to observe colleagues who can serve as mentors and models.

Limitations

Students with low measured self-determination. This study did not include students with low measured self-determination. Students who submitted consent forms and completed the survey did not have low measured self-determination, which affected the qualitative phase. This result was echoed in a larger study conducted on students in court schools (Glassett, 2012). In that study, students with low measured self-determination could not be included in the qualitative phase due to incarceration or disenrollment from court schools. The voices of students with low measured self-determination have not been heard. Further research that specifically includes this group would add to the SDT field, suggest education reform, and give voice to these currently unheard students.

Generalization. This study was conducted in one Montessori adolescent program in one southwestern California school. The number of Montessori adolescent programs throughout the United States and the world is small, and they vary in their implementation and development. Although certain characteristics are foundational to Montessori methodology and practice, the degree to which they are authentically represented also varies. In addition, while the study was designed to include students with low, medium, and high self-determination, the seventh-grade students who participated in the quantitative phase represented students with medium-to-high overall self-determination. The voices of students with low self-determination were not captured. The stories that were presented and analyzed give readers a taste of the lived experience of seventh-grade students in the Montessori adolescent program but cannot possibly be extrapolated to this school's entire seventh-grade community, much less all seventh graders who attend Montessori adolescent programs.

Narrative inquiry does not seek to generalize findings. Rather, its purpose is to capture the stories of individuals or groups and to faithfully analyze and retell the authentic stories of study participants. Without bias, I put aside knowledge of the individuals and remained open to the perceptions and meanings in each participant's narrative. The purpose of this study was to give voice to the voiceless. The voices of the students add to existing literature on Montessori methodology, middle-level education, and SDT.

Conclusion

This study was guided by the research question, What effect, if any, would a learning environment designed to support the development of autonomy, competence, and relatedness have on the students' development of self-determination during their seventh-grade year? The voices of the participants in this study give a description of the lived experiences of these students over a 7-month period. Their responses clearly indicate an overall feeling of autonomy, competence, and relatedness. In their own words, students mentioned the same supports described by Montessori (1972b) and designed by Coe (1996). While their feelings did not change over the time of the study, their repetition of themes and responses provide a robust narrative description of their seventh-grade year. Each recurring code and theme corroborates the theory that supports for autonomy, competence, and relatedness were incorporated in the adolescent program.

The supports mentioned by students are hallmarks of Montessori methodology at every level; however, they can be implemented in any school. Both AMLE (2000) and the NETP (2010) have lauded these same supports. Implementing these supports requires a shift from an age-old paradigm. Administrators must lead the reform through both the inclusion of practices that support teachers and the creation of high-trust schools. We must include these supports to provide the education that all children deserve.

AUTHOR INFORMATION

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