International Journal of Virtual and Personal Learning Environments
Volume 14 • Issue 1 • January-December 2024

Beliefs in Online Professional Learning in Early Mathematics Teaching and Their Effects on Course Engagement

Jessica Heather Hunt
North Carolina State University, USA

Brianna Bentley
https://orcid.org/0009-0007-9420-0546
William Peace University, USA

Alejandra Duarte
IXL Learning, USA

ABSTRACT

This study focused on the effects of an early math online professional learning course offered to preschool teachers. The course was designed to inform participants' knowledge of developmental progressions and promote daily mathematics instruction that encouraged students to view their world through a mathematical lens. A survey of preschool teachers' beliefs was administered to participants of the course to determine if participants' beliefs changed significantly and how their pre-course beliefs influenced their engagement in the course. Findings indicate that the course impacted preschool teachers regardless of their area of responsibility, education level, or experience level. The teachers' comfort with teaching math to young children and perspectives about age appropriateness of mathematics were both positively influenced by the course. The teachers with the most positive initial beliefs had a higher rate of course completion. Implications for the field of preschool teacher education and online professional learning environments are discussed.

KEYWORDS

Early Childhood, Mathematics, Online Learning, Teacher Development

BELIEFS IN ONLINE PROFESSIONAL LEARNING IN EARLY MATHEMATICS TEACHING AND THEIR EFFECTS ON COURSE ENGAGEMENT

Despite the vast informal mathematical knowledge that young children might bring at the beginning of their school experience (National Research Council, 2001), differences in mathematics achievement often become evident before kindergarten (Shah et al., 2018). These differences can impact children's mathematics learning in the long run if they are unaddressed in the early years (National Mathematics Advisory Panel, 2008). Children from low-resource communities tend to have more limited opportunities for school and non-school (e.g., preschool, daycare, home) learning than their peers with increased financial and educational means, which contributes to such disparities (Raudenbush, 2009; Rawlings et al., 2023). In school settings, teachers have the potential for the greatest positive impact on student achievement among school-based variables (Hart et al., 2024;

DOI: 10.4018/IJVPLE.357305

Opper, 2012). Thus, it is essential for teachers to continue to develop their knowledge of effective ways to teach mathematics to all young children.

While teachers' knowledge of math content and pedagogy matters, their beliefs also play a major role in what and how they teach (Leijen et al., 2024; Polly et al., 2013; Wilkins, 2008). Specifically, in early childhood, teachers may prioritize other types of learning over mathematics, arguably due to their beliefs about their own ability to support children's mathematical learning or the appropriateness of including mathematics in the preschool curriculum. One way to address this issue is teacher professional development that is designed to challenge such beliefs. Accordingly, this paper reports on the development and study of an online professional development course, Teaching Math to Young Children, based on the 2013 Institute for Education Sciences practice guide. The course was designed to support participants' understanding of developmental learning progressions and promote daily mathematics integration and instruction. Course content encouraged participants to use activities that support young students to view their world mathematically. This study reports on the impact of the course on shifting participant beliefs. More specifically, the authors analyzed shifts in teachers' beliefs in terms of level of education and experience. The authors also analyzed whether participants' pre-course beliefs impacted the nature of their course engagement.

REVIEW OF LITERATURE

Teaching Math to Young Children

Research and various national organizations have outlined the type of mathematics that should be supported in early childhood classrooms. Specifically, the National Council of Teachers of Mathematics and the National Association for the Education of Young Children (NAEYC & NCTM, 2010) recommend carefully planned mathematics instruction grounded in knowledge of young children's development that builds on informal mathematics knowledge. In 2013, the Institute of Education Sciences (IES) released a practice guide with five recommendations for teaching mathematics to young children. The first two recommendations in the IES practice guide focus on using developmental progressions to teach mathematics, with Recommendation One focused on numbers and operations and Recommendation Two focused on geometry, data, and measurement. Developmental progressions can serve as a road map for math instruction based on empirically tested hypotheses of how students' mathematical activity develops along a learning trajectory (Siemon, 2021). At the time the guide was written, the IES reviewed ten studies of instruction that relied on developmental progressions for numbers and operations with positive effects on children's early math achievement (Frye et al., 2013).

It is widely agreed upon that educators must determine what their students know in order to plan effective instruction (Farhang et al., 2023; Findell et al., 2001; NAEYC, 2009). Furthermore, such assessment does not occur at just one point in time but rather must happen continuously so that learning activities are connected to students' developmental needs (NAEYC & NCTM, 2010). Continuous progress monitoring is encouraged in Recommendation Three and is essential to the successful implementation of the first two recommendations. In the studies reviewed by IES, larger positive outcomes were associated with interventions that included regular assessment (Frye et al., 2013), which supports the call for ongoing formative assessment in Recommendation Three.

Children encounter mathematics throughout their lives, out in public, during home and school routines, and through various forms of play. They bring raw mathematical knowledge to school based on all these experiences (DePascale & Ramani, 2024; Findell et al., 2001). Recommendation Four focuses on supporting young children to make connections between their daily encounters and more formal mathematics concepts. Similarly, Recommendation Five advocates for educators to provide consistent opportunities for children to engage in mathematics, both through formal instruction and by incorporating it into play and routines. Particularly for students who enter school with fewer mathematical learning experiences, dedicated instruction has proven to support young students' short- and long-term numerical understanding (Dyson et al., 2011; Jordan et al., 2012). However, priorities in early childhood classrooms tend to lie with social and emotional learning, which results in an avoidance of such formal mathematics instruction (Elizarov et al., 2024; Kowalski et al., 2001; Lee, 2006). Experts emphasize integrating engaging and developmentally appropriate instruction with other activities, like play, routines, and learning in other disciplines (NAEYC, 2009; NAEYC & NCTM, 2010).

Incorporating daily math instruction as envisioned in Recommendation Five relies heavily on the implementation of the other four recommendations. Children are much more likely to be successful in mathematics when given the opportunity to attach concepts to a context, like a game or life experience (Chen, 2024; Findell et al., 2001; Siegler & Ramani, 2008). In addition, educators must use progress monitoring to determine the appropriate next steps for their students in each developmental progression. A wealth of evidence supports the positive effects of the recommendations in the IES guide, especially when they are implemented together (Frye et al., 2013). Therefore, it is essential to equip teachers of young children with knowledge, tools, and strategies that help them get to know their students so they can provide them with deep, developmentally appropriate mathematics experiences every day (Frye et al., 2013).

Beliefs and Teaching Early Mathematics

A teacher's beliefs about teaching early math can impact how and what they teach their students. In addition to needing access to and knowledge of resources that support strong teaching practices, teachers' beliefs need to be aligned with those practices, or they may not enact them. Teachers' development of beliefs and knowledge about teaching stem from three types of experiences: personal, schooling and instruction as students, and formal knowledge related to subject matter (Leijen et al., 2024). A common belief of students and teachers is that individuals' math achievement depends on innate intelligence and ability (Clements & Sarama, 2016; Dweck, 1999). This belief is misguided and can damage individuals' perceptions of their mathematical ability.

Early childhood teachers have historically favored socio-emotional learning and believe that these skills are more important for preschoolers to learn than math (Wu et al., 2024). In addition, the majority of early childhood teachers do not feel prepared to incorporate STEM instruction into their classrooms (Park et al., 2017) and possess negative dispositions toward mathematics, such as dislike, fear, and doubt in their own abilities (Chen et al., 2014; Gerde et al., 2018). Teachers voiced that lack of time, instructional resources, professional development, administrative support, knowledge about STEM topics, and teacher collaboration were all challenges they faced when teaching math in their early childhood classroom (Park et al., 2017).

Recent studies have found that early childhood teachers believe that the incorporation of math into their classroom is important and developmentally appropriate (Chen et al., 2014; Lee & Ginsburg, 2007; Moomaw, 2024; Park et al., 2017) and that preschoolers are interested in learning math and need it to be prepared for kindergarten (Chen et al., 2014; Lee & Ginsburg, 2007). A majority of preschool teachers were confident that they knew the best practices and strategies for teaching math, reasonable math goals for preschoolers, how to plan activities to help preschoolers learn math, and how to incorporate math learning into familiar preschool activities, like dramatic play (Moomaw, 2024). Yet, preschool teachers were not confident in their own ability to do math (Chen et al., 2014). This discrepancy is significant and suggests the need for professional development that addresses teachers' confidence in their own math abilities. One way to provide access to such professional development for a wide range of teachers is via online learning platforms.

Online Platforms for Teacher Learning

The development of online learning platforms has widened opportunities for how we can conceptualize professional development for teachers. Online learning environments expand teachers' networks beyond their local setting, allow flexibility in participation schedules, and provide opportunities for those who have limited access to professional development (Archambault et al., 2022; Whitehouse et al., 2006). Online learning can include sessions that are live, asynchronous, or some combination of both. One type of online professional learning experience that is common across many fields is a massive open online course (MOOC), such as those offered by third-party platforms such as edX or Coursera. The content in MOOCs is typically delivered asynchronously, yet even within this type of delivery, there are a variety of possibilities for course format. The typical MOOC usually includes teacher-led activities, readings, assessments, and a space for interacting with other participants, such as a discussion forum (Archambault et al., 2022; Hollands & Tirthali, 2014).

Many of the same features of strong professional development design apply to online professional learning. Darling-Hammond et al. (2017) identified seven features that are commonly used to support effective professional development: sustained duration, coaching and/or expert support, active learning experiences, opportunities for collaboration, a subject-matter content focus, feedback and reflection, and the use of models and modeling. The elements of a content matter focus, sustained duration, the use of models and modeling, and reflection can be easily transferred into a MOOC context: A content focus is often embedded from the start (e.g., Brennan et al., 2018; Vivian et al., 2014), learning modules can be organized to span several weeks or even months (e.g., Boltz et al., 2021; Hollebrands & Lee, 2020), instructors can provide models of strong practice through vignettes or videos (e.g., Cox et al., 2023; Hollands & Terthali, 2014; Vivian et al., 2014), and teachers can reflect on their learning formally in the course and informally on their own. The other features, including coaching or expert support, active learning experiences, feedback, and opportunities for collaboration, are participatory and interactive in nature, thus requiring more intentional planning within an asynchronous MOOC. To promote meaningful participation by teachers, research on designing MOOCs to support teacher learning emphasizes the need to continually refine online professional learning experiences in response to teachers' needs and their approaches to engaging with the course (Brennan et al., 2018; Cox et al., 2023). It stands to reason that a MOOC designed to promote relevant, active, and collaborative learning among teacher participants would be more successful in comparison to a similar course excluding those features. One way of measuring the success of a MOOC is to analyze the level and type of engagement by participants, with certain types of engagement indicating a MOOC reached more participants at a deeper level and, as a result, could have a greater impact.

Engagement in Online Platforms for Teacher Learning

Engagement is historically defined by three dimensions: (a) behavioral engagement; (b) emotional engagement; and (c) cognitive engagement. Behavioral engagement reflects the participation of an individual for the purpose of achieving a positive outcome, such as passing a course. Emotional engagement includes the positive and negative reactions that ultimately influence an individual's willingness to complete a task. Cognitive engagement involves an individual's motivation and their investment in learning (Fredricks et al., 2004). Although these broad definitions capture engagement in a holistic sense, more contemporary work has captured engagement in terms of online professional learning courses, such as MOOCs.

For example, Milligan et al. (2013) created a framework for MOOC engagement based on self-reported data (participant surveys, interviews). Three types of engagement were identified: active participants, passive participants, and lurkers. Active participants were defined as course completers who connected with other participants of the MOOC through social media interactions and comments on the online blog posts. Passive participants expressed frustration and dissatisfaction with the format of the MOOC because they were looking for a more formal course format or they had difficulty with the interactive nature of the course and struggled to connect with their peers. The majority of participants were identified as lurkers and included those who were actively following the course but were not engaging with their peers within the MOOC through activities such as forums or discussion posts. Participants who were classified as lurkers made an active choice to engage at that level and found their experiences in the MOOC to be valuable (Milligan et al., 2013). Lurking is a common occurrence in online courses, and lurkers have been portrayed as problematic for building a sense of community (Venter, 2024) since they reap benefits from the course while acting as bystanders to course discussions, which demonstrates a lack of commitment to the learning community (Rovai, 2000). What is not yet known is how these profiles impact learning or alter participants' beliefs, especially about early mathematics teaching and learning.

Other researchers frame MOOC engagement through patterns in learning analytics across a MOOC as opposed to the self-reporting of participants. For example, Kizilcec et al. (2013) developed a framework for MOOC engagement consisting of four trajectories of engagement based on types of student participation across the courses studied: completing, auditing, disengaging, and sampling. Similar investigations of MOOC engagement take a related approach, examining engagement patterns throughout modules of a course and then identifying cluster patterns. Ferguson et al. (2015) employed such clustering to investigate how engagement patterns vary according to course design factors. Similarly, Anderson et al. (2014) developed another taxonomy of engagement patterns, accompanied by an analysis that recognized the nuances of what it means for a MOOC participant to gain value from and put effort into a course. What has not yet been reported is how participants' real-time engagement profiles impact beliefs about content, learning, or teaching, whether more generally or with regard to early math in particular.

Several factors affect student engagement in a MOOC (Yu et al., 2024), including students' confidence to share their work in an online community (Yu et al., 2024), whether students have prior experience participating in a MOOC, and students' motivation to learn (Milligan et al., 2013; Yu et al., 2024). Reasons for students' lack of engagement and ultimate dropout of a MOOC include: (a) enrolled with no real intention to complete; (b) lack of time; (c) course difficulty and lack of support; (d) lack of digital skills or learning skills; (e) bad experience while participating in the MOOC; (f) feelings of isolation and lack of engagement with their peers; (g) enrolled with unrealistic expectations of the MOOC format; (h) started late; and (i) if the MOOC relies heavily on peer review (Onah et al., 2014; Sunar et al., 2016). MOOCs can have a high impact, even on participants who do not complete them as intended. Kizilec et al. (2013) highlighted that “auditors,” sometimes known as lurkers, reported an overall experience in their MOOC similar to levels reported by “completers.” It was those who were only sampling the course or whose participation trailed off after completing initial modules who rated their overall experience at lower levels (Kizilec et al., 2013). Onah et al. (2014) suggests that adaptability and choices within the structure of MOOCs could give participants a chance to complete all the learning objectives at their own pace when it is convenient for them, which would honor the learning potential for engagement profiles that might differ from a traditional “completer” (Kizilec et al., 2013).

The Current Study

While much work in MOOCs has been done to describe teacher learning, contemporary work has not been done in early mathematics or with teachers of early mathematics (e.g., Amador et al., 2023). Therefore, in this paper, the authors were interested in learning whether engaging in an online professional development course would significantly alter participants' beliefs about early mathematics teaching and learning and how changed beliefs might vary across participant backgrounds. The authors were also interested in whether participants' pre-course beliefs would impact course engagement in differential ways. The following research questions were addressed:

- **Research Question 1:** Did participant beliefs, as measured by the Mathematical Development Beliefs Survey, significantly change before and after engaging in early math online professional learning? Did changes in participant beliefs vary across years of experience and education level?
- **Research Question 2:** Did participants' pre-course beliefs influence their course engagement?

METHODS

Aims of the Study

This paper reports on the second iteration of the Please define TMYC here (TMYC) online professional learning course offered through a large research university. This iteration of the course enrolled 608 participants and used Moodle to both build and deliver the course experience. The course was offered in the Spring of 2021, opening in January and remaining open through May. The content of the introductory unit and five core content units that comprised the course were described in the literature review. New units were released each week for seven weeks (i.e., the introductory unit, five core content units, and a concluding unit). Announcements were released weekly to discuss course activity and to remind participants about course activities. Participants could begin the course at any point and were free to interact with all, some, or none of the course materials and units. After the course closed, discussions and other activities remained available to course participants in a "read-only" format.

The Spring 2021 course offering represents a revised experience based on data from the pilot run (see Hunt et al., 2023a). Revisions were made to this iteration based on preliminary qualitative analysis for the course pilot, in which the first and second authors noticed participants frequently framing their talk about students through a deficit lens. Two major changes were made to counter this observation. First, the order of the units was changed such that unit four, which is focused on supporting children's mathematical view of the world, became unit one. This was intended to help participants see children as holding mathematical knowledge before entering a school context. Second, the new unit one was revised to include information about how our disposition toward math as educators and adults in general can be transmitted to children. This was included to help orient participants toward fostering a love of mathematics in young children. Furthermore, in the new unit two (formerly unit one), content and activities were added to distinguish between fixed and growth mindsets, and participants were asked to think about how they would respond to deficit language used by others. The purpose of these additions was to help shift the discussion forum conversations toward strengths-based thinking about students.

Participants

Participants who were enrolled in the TMYC online professional learning course were considered for study inclusion. For inclusion in the sample to examine changes in participant beliefs, participants had to be: (a) enrolled in the course; (b) completed both the pre- and post-survey of beliefs (described below); and (c) engaged in at least three of the five course units. For inclusion in the sample to examine the effects of pre-course beliefs on participant engagement, participants had to be: (a) enrolled in the course; (b) completed the pre-survey of beliefs (yet not the post-survey); and (c) engaged in at least three of the five course units. One hundred and two participants and 296 participants, respectively, met the above criteria and were included in the study. Table 1 provides information about the course participants' educational background and work experiences.

Data Sources

Data sources included a validated survey of teacher beliefs about mathematics development and course log data files related to participants' engagement. Each data source is described below.

Teacher Beliefs

Because the ultimate purpose of this study is to examine changes in teachers' beliefs about teaching mathematics to young children and how pre-course beliefs impacted course engagement, the Mathematical Development Beliefs Survey (Platas, 2014) was used to measure changes in participants' self-reported beliefs before and after the course. The survey measures respondents' beliefs about the development and teaching of early mathematics and contains 32 items across three constructs: (a)

Table 1. Course participant demographics

Identified Role		Experience Level in Early Mathematics Education		Grade Level Specification	
Classroom Teachers		No Experience	9%	Pre-K	7%
Curriculum & Instruction	7%	Less Than 2 Years	11%	Kindergarten	15%
Special Education	12%	2–5 Years	20%	Elementary	54%
School Admin & Support Staff	3%	6–15 Years	42%	Middle and/or High School	5%
Teacher Prep	3%	16+ Years	18%	Post-Secondary	0%
Other	10%			Not Provided	19%

Note. The numbers in this table indicate the number of course participants who identified themselves within each role, experience level, and grade level.

Table 2. Mathematical beliefs survey sample items

Construct	Sample Statement
Classroom locus of generation of mathematics knowledge	The teacher should play a central role in mathematical instruction.
Age appropriateness of mathematics as a school subject	It is better to wait until kindergarten for math instruction.
Teacher confidence with classroom support of mathematical development	I am unsure how to support math development for young children.

classroom locus of generation of mathematical knowledge (12 items); (b) age appropriateness of mathematics as a preschool subject (10 items); and (c) teacher confidence with classroom support of mathematical development (10 items). Responses are supported by a five-point Likert scale, with response options ranging from Strongly Agree (5) to Strongly Disagree (1). Higher scores reflect the greater perceived value of participants. Cronbach's alpha of the measure ranged from 0.84 to 0.93 (Platas, 2014). Table 2 lists sample items.

The Mathematical Development Beliefs Survey was administered pre- and post-completion of the TMYC course. Respondents provided answers to 32 items ranging from Strongly Agree (5) to Strongly Disagree (1). Of the 32 items, seven items required reverse coding such that Strongly Agree=1 and Strongly Disagree=5. Survey results were computed by identifying the sum of all rating scale items (range 0–160), the average rating scale score (range 1–5), and the percentage of raw score out of total possible points (range 0–100).

Course Log Data Files

Course log files were used to determine different engagement profiles of participants in the course. Specifically, the log files were examined to determine if participants (a) completed the pre-survey; (b) watched course videos and/or read course resources; (c) wrote in course Notice and Reflect forums; (d) accessed the course's additional information and materials (i.e., “Deep Dive” materials); and/or (e) completed the course post-survey. From this examination, two different user engagement conditions were defined: (a) participants who submitted the pre-course beliefs survey and completed all activities (b–d above) in the full course (“completed”) and (b) those who submitted the pre-course beliefs survey and did not complete the course but engaged in discussion forums in the course (“write activity”). The two definitions were used to address the second research question.

Table 3. Descriptive statistics for overall pre- and post-course beliefs survey results

Survey (n)	Raw Score M (SD)	Rating Scale M (SD)	Percent M (SD)
Pre (n=296)	99.65 (9.50)	3.11 (0.30)	62.28 (5.94)
Post (n=103)	106.21 (7.87)	3.31 (0.25)	66.38 (4.92)

Note. SD = standard deviation.

Study Design and Data Analysis

To address the research questions, the authors used a single-arm—one-group pre-post study design with one phase of data collection. To evaluate whether there were changes in participants' beliefs before and after taking part in the course, a series of dependent sample t-tests were conducted. Specifically, changes were compared for the overall survey score as well as for each of the three subscales. Effect sizes were calculated using Cohen's d, such that 0.2 is small, 0.5 is medium, and 0.80 is large (Cohen, 1988; Martin & Martinez, 2023). A series of one-between, one-within mixed analysis of variances (ANOVAs) were conducted to determine if there was a significant interaction between the between-subjects factor of time (pre vs post) and the within-subjects factor of each of the three educator demographics (responsibility, education level, and experience level) on beliefs survey score. The three educator demographic variables and their categories are: (a) primary area of responsibility (classroom teacher or other educator); (b) education level (4-year college degree or graduate degree); and (c) experience level (1–5 years or 6–15+ years). Finally, to evaluate differences in pre-course beliefs survey scores based on user engagement conditions, an independent samples *t*-test was conducted.

RESULTS

In this study, the authors sought to evaluate if participants' beliefs about mathematics learning in the early years, confidence in supporting children's mathematical development, and perspectives about who holds the locus of mathematics knowledge changed significantly after engaging in an online professional learning experience. The authors were also interested in determining whether participants' pre-course beliefs affected their levels of course engagement. The results of the study are presented below.

Overall Pre- and Post-Course Survey Results

Table 3 shares the descriptive statistics for the survey results at both pre- and post-course completion. Scores increased from pre- to post-course by an average of 6.56 points. The mean rating scale level did not substantially increase from pre (3.11) to post (3.31), as it remained slightly above “Neutral.” The percentage of scores increased from 62% to 66% from pre- to post-course completion.

The pre- and post-survey results for each subscale are shared in Table 4. The increase from pre- to post-course scores was largest for the comfort subscale (5.36), followed by the locus subscale (0.74) and the age subscale (0.46).

Pre- and Post-Course Differences in Participant Beliefs

The results from the dependent samples *t*-tests indicate there is a statistically significant difference in overall TMYC beliefs survey from before to after engagement in the TMYC course; $t(102)=7.48$, $p<0.001$, with a moderate effect size (Cohen's $d=0.74$). Also, there was a significant change from before to after completion of the course for the comfort subscale; $t(102)=9.15$, $p<0.001$, with a large

Table 4. Descriptive statistics for each subscale pre-and post-course beliefs survey results

Survey (n)	Locus[1] M (SD)	Age[2] M (SD)	Comfort[3] M (SD)
Pre (n=296)	33.03 (6.27)	29.47 (2.52)	37.15 (7.33)
Post (n=103)	33.77 (6.06)	29.93 (2.35)	42.51 (5.15)

Note. [1]Total possible Locus subscale score is 60. [2] Total possible Age subscale score is 50. [3] Total possible Comfort subscale score is 50.

Table 5. Descriptive and inferential dependent samples t-test results for differences in beliefs survey scores and its subscales from pre- to post-course completion

Group	Mean Raw Score	SD	*df*	*t*	*p*	Cohen's *d*[a]
Pre Overall	100.23	9.23	102	7.48[b]	<0.001	0.74
Post Overall	106.21	7.87				
Pre Locus	33.52	5.77	102	0.54	0.295	0.05
Post Locus	33.77	6.06				
Pre Age	29.32	2.14	102	2.08[b]	0.020	0.20
Post Age	29.93	2.35				
Pre Comfort	37.39	6.74	102	9.15[b]	<0.001	0.90
Post Comfort	42.51	5.15				

Note. [a] Cohen's *d* interpretation: small=0.2, medium=0.5, and large=0.80. [b] Significant *t*-statistic, $p<0.05$.

effect size (Cohen's $d=0.90$) and for the age subscale; $t(102)=2.08$, $p=0.020$, with a small effect size (Cohen's $d=0.20$). The locus subscale was not significantly different ($p>0.05$), as shown in Table 5.

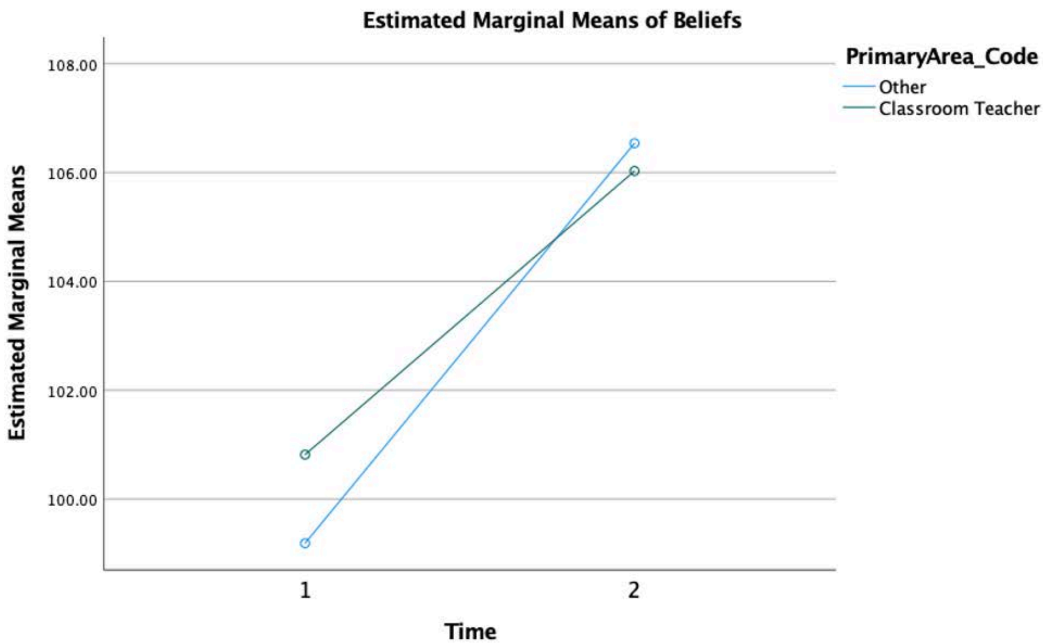
Pre- and Post-Course Differences Between Educator Demographics

The descriptive statistics for each demographic variable are shared in Table 6.

Table 6. Descriptive statistics comparing pre- and post-course beliefs survey between educator demographics

Time	Educator Demographic (n)	Mean	SD
Pre	Classroom Teacher (n=66)	100.82	9.39
	Other Educator (n=37)	99.19	8.99
Post	Classroom Teacher (n=66)	106.03	7.41
	Other Educator (n=37)	106.54	8.73
Pre	4-year College Degree (n=51)	100.53	9.65
	Graduate Degree (n=49)	99.59	8.83
Post	4-year College Degree (n=51)	106.35	7.67
	Graduate Degree (n=49)	106.00	8.27
Pre	1–5 years experience (n=34)	100.77	9.30
	6–15+ years experience (n=41)	100.34	8.82
Post	1–5 years experience (n=34)	107.32	7.31
	6–15+ years experience (n=41)	105.95	7.44

Figure 1. Profile plot differences in beliefs survey score from pre- to post-course between educator responsibility



The profile plot from each of the three one-within, one-between mixed ANOVAs are shared in Figure 1, Figure 2, and Figure 3. The profile plots for responsibility (Figure 1) suggest potential interaction, while the almost parallel lines for education (Figure 2) and experience (Figure 3) suggest no interaction.

Reviewing the inferential results from Table 7 indicates there are no significant interactions for any of the groups.

Given the absence of a significant interaction, the main effects can be interpreted for these tests. There are significant main effects of time for responsibility ($p<0.001$), education ($p<0.001$), and experience ($p<0.001$), with large effect sizes such that 36% to 40% of the variance in beliefs score is accounted for by time ($\eta^2 = 0.362$ to 0.403). These findings suggest that educators' belief scores significantly increased from pre- to post-course, regardless of their primary area of responsibility, education level, and experience level.

Differences in Pre-Course Scores Between Engagement Conditions

Finally, an independent samples *t*-test was conducted to compare differences in pre-course beliefs survey scores based on user engagement conditions. There is no significant difference in pre-course beliefs survey score between the two engagement conditions, $t(232)=0.987$, $p=0.325$. While pre-survey beliefs scores were more positive for the completers, the difference was not statistically significant and SDs were similar, as shown in Table 8.

DISCUSSION

Teachers' beliefs are a vital foundation from which teachers enact pedagogy (Leijen et al., 2024; Polly et al., 2013; Wilkins, 2008). Specifically, teachers' confidence in supporting children's mathematical development, beliefs regarding who holds the locus of mathematics knowledge, and the importance of mathematics learning can impact children's mathematics experiences in the

Figure 2. Profile plot differences in beliefs survey score from pre- to post-course between educator level of education

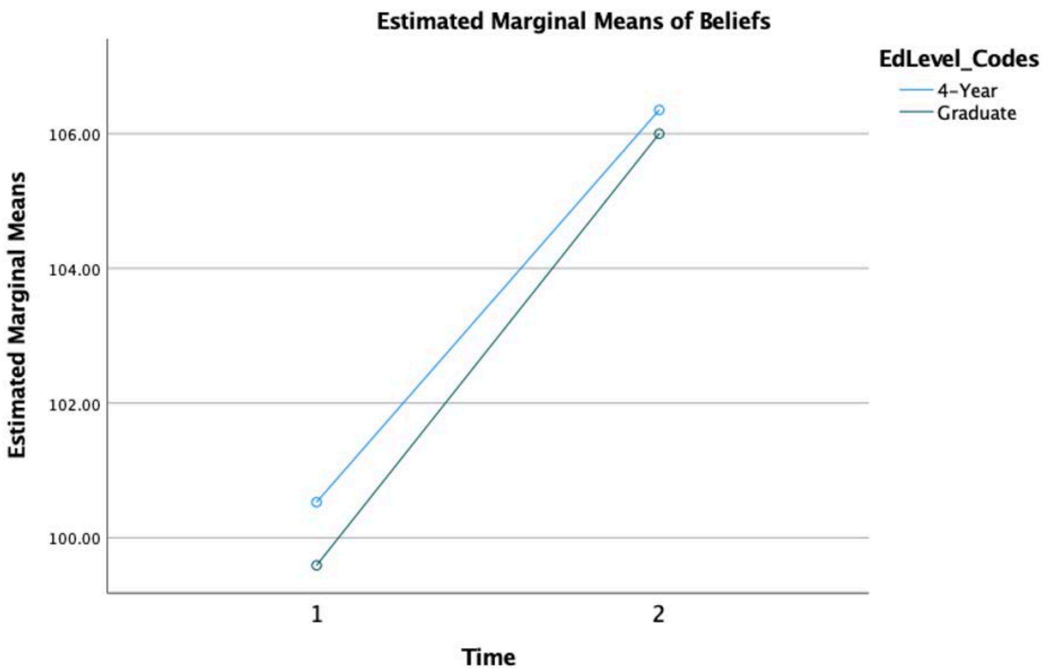


Figure 3. Profile plot differences in beliefs survey score from pre- to post-course between educator level of experience

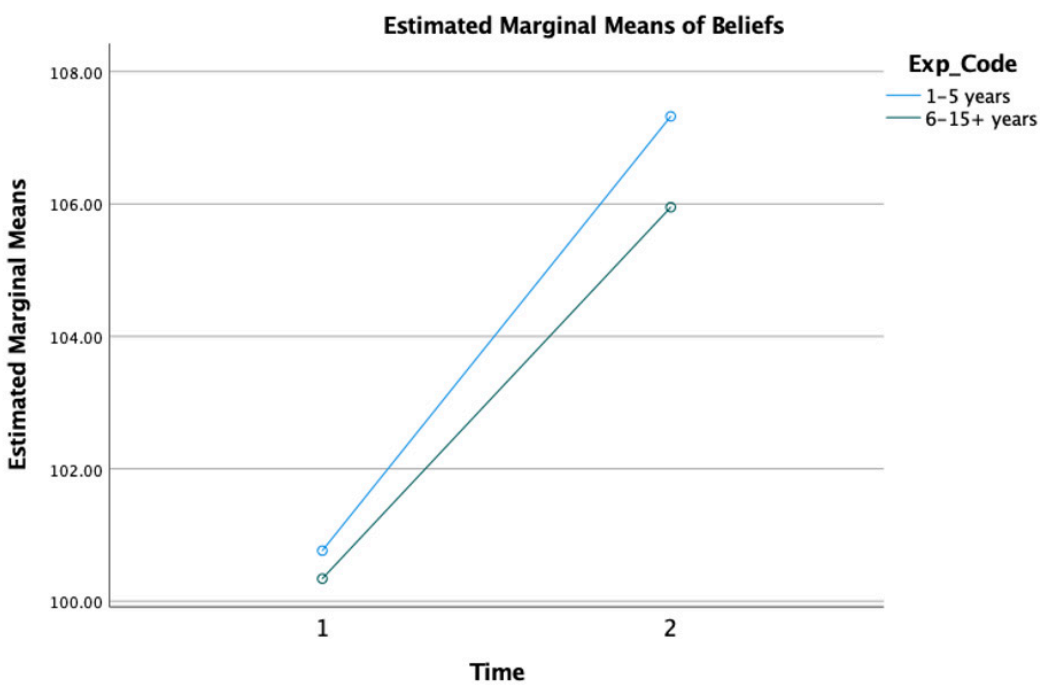


Table 7. Summary table for two-way mixed ANOVA of the effects of time and educator type on belief survey scores

Source	*df*	*SS*	*MS*	*F*	*p*	η^{2a}
Between subjects for Responsibility						
Responsibility	1	14.84	14.84	0.129	0.721	0.001
Error	94	13,386.08	142.41			
Within subjects for Responsibility						
Time	**1**	**1871.10**	**1871.10**	**57.237**	**<0.001**	**0.362**
Time x Responsibility	1	54.25	54.25	1.659	0.201	0.016
Error	101	3301.73	32.69			
Between subjects for Education Level						
Education	1	20.81	20.81	0.180	0.672	0.002
Error	98	11335.57	115.67			
Within subjects for Education Level						
Time	**1**	**1869.43**	**1869.43**	**55.742**	**<0.001**	**0.363**
Time x Education	1	4.271	4.271	0.127	0.722	0.001
Error	94	2,713.74	28.87			
Between subjects for Experience Level						
Experience	1	29.96	29.96	0.276	0.601	0.004
Error	73	7913.61	7913.61			
Within subjects for Experience Level						
Time	**1**	**1376.10**	**1376.10**	**49.265**	**<0.001**	**0.403**
Time x Experience	1	8.371	8.371	0.300	0.586	0.004
Error	73	2039.07	27.932			

Note. [a] Eta-squared interpretation: small=0.01, medium=0.06, large=0.14.

preschool setting (Platas, 2014). Online professional learning opportunities are designed to provide opportunities for teachers to engage in activities designed to challenge their beliefs and impact their mathematics teaching in the early years. Yet, more research is needed to understand whether these resources actually impact teacher beliefs and, relatedly, if teachers' existing beliefs impact their course engagement, especially in the context of early mathematics, where there is little to no research and a need for development that fosters productive beliefs.

This work adds to the literature base in that this paper studied whether engaging in an online professional development course would significantly alter participants' beliefs about early mathematics teaching and learning. This study also examined how changed beliefs might vary across participant backgrounds and whether participants' pre-course beliefs would impact course engagement in

Table 8. Descriptive and inferential independent samples t-test results for differences in pre-course beliefs survey between engagement groups

Engagement Group (n)	Mean Score	SD	*t*(232)	*p*
Write Activity (n=152)	99.38	9.64	0.987	0.325
Completed (n=82)	100.66	9.06		

important, differential ways. Below, the authors summarize the findings of this work, relate it to the broader literature on teacher beliefs and early mathematics teaching, and speak to considerations for further research.

Supporting Teachers' Positive Beliefs About Teaching Early Childhood Mathematics

Differences in the mathematics achievement of young children that can impact long-term learning often become apparent before formal schooling (Hart et al., 2024; Shah et al., 2018). Yet, in early childhood, teachers often de-emphasize the learning of mathematics, which can be a result of teachers' beliefs regarding the appropriateness of including mathematics in the preschool curriculum or their own ability to support it. In this study, it was found that, overall, participants who engaged in the online professional learning course significantly and positively impacted their beliefs about teaching mathematics to young children to a moderate degree. Specifically, significant growth was detected within the age and comfort subscales but not within the locus subscale. Such findings indicate the course particularly impacted participants' comfort level with teaching math to young children and age appropriateness of mathematical development, with less of an impact on locus of generation of mathematics knowledge. The reduction in standard deviation pre- and post-course also indicates that there was more unity in informants' attitudes related to early mathematic teaching and learning post-course.

It was also found that, despite varied education and experience levels, the course benefited all participants. The absence of significant interaction between impacted beliefs and education level, primary area of responsibility, or experience level suggests that educators benefited from the course regardless of their primary area of responsibility, education level, or experience level. The ability of the course materials to positively impact a wide variety of teachers' beliefs is encouraging, as preschool teachers are often not confident in their own ability to do math at a time when preschoolers are interested in learning math and need it to be prepared for kindergarten (Chen et al., 2014; Hart et al., 2024; Lee & Ginsburg, 2007). It is also encouraging in light of common negative beliefs that teachers often hold regarding students, such as believing that only innate ability and intelligence support math learning in the early years (Clements & Sarama, 2016; Dweck, 1999) and that these beliefs can negatively impact students' learning experiences (Gerde et al., 2018; Wu et al., 2024). To that end, future research related to this course in particular might investigate if and/or how teachers' changed beliefs impact classroom practice and the potential of online professional development courses to make a positive impact on early childhood teachers given the number of people it has the potential to reach.

Finally, the authors sought to understand how prior beliefs impacted participants' engagement patterns within the MOOC itself. To do so, the authors noted two distinct engagement conditions in the course—those who completed all activities and completed the pre-source survey on beliefs (“completers”) and those who did complete the pre-course survey on beliefs but did not complete the course but engagement in write activity (“write activity”). The authors then evaluated differences in pre-course beliefs survey scores based on the two user engagement conditions. While prior work has examined beliefs regarding early math (Park et al., 2017) or created engagement profiles of participants as they learn within a MOOC and linked the profiles to participant learning (Ferguson et al., 2015; Kizilcec et al., 2013), no such prior research links participants' pre-course beliefs to their engagement in MOOCs designed to challenge those beliefs, especially with regard to early math teaching and learning.

To that end, the authors found no significant difference in pre-course beliefs survey score between the two engagement conditions. Participants in the “completers” profile and the participants in the “write activity” profile did not differ in their beliefs about classroom locus of generation of math knowledge, age appropriateness of math as a school subject, or confidence with classroom support of math development, although “completers” did evidence slightly more positive beliefs overall before beginning the course. The finding that participants' beliefs did not impact teachers' course engagement is novel and worthy of future research to expand the knowledge base beyond the results of the current study. Although the results of this study suggest that incoming beliefs may not play a significant role in the ways participants choose to engage in MOOC content, it is not yet known if pre-course belief survey results have the potential to impact participants' future engagement in courses in other contexts and contents.

Future research should further investigate potential impacts of beliefs on course engagement patterns and the impact on changed classroom practice. For example, if the beliefs of teachers differ significantly from the perspectives of a program or recommended practice, then further efforts should be made to provide opportunities for teachers to reflect upon and shape their beliefs over time (Hunt et al., 2023b). Although revisions to the course content were made in the previous iteration of the course to provide additional learning opportunities (Hunt et al., 2023a), future iterations of the course might employ design changes, such as adaptability and choices within the structure of the course and testing their effects on teachers' engagement and relationships to their incoming and changing beliefs.

Finally, engagement in online professional learning courses might be interconnected with participants' initial beliefs and knowledge as well as barriers they face in course engagement.

It is possible that other factors, such as teachers' goals, lack of time, digital learning skills, state starts, feelings of isolation within the online structure, or other factors, influenced course engagement or interrelated with beliefs in important ways (Onah et al., 2014). MOOCs can have a high impact, even on participants who do not complete them as intended (Kizilec et al., 2013). Attending to course design principles that might alleviate barriers to engagement or further bolster productive beliefs is worth further investigation. For example, future research might formally test intersections of incoming beliefs, varied iterations of course design, and participant outcomes across a wide demographic of teacher participants.

Limitations

There are important limitations in this work that need to be discussed. First, the difference in the number of participants between the pre-course (296) and post-course (103) surveys is notable. Having a lower number of participants in the post-course survey could potentially raise concerns about the representativeness and generalizability of the findings. Reported reasons behind the drop in participation include teachers' time and availability to complete the modules in full (Onah et al., 2014) as well as study attrition. Related to the first point, the smaller post-course sample size could introduce sampling bias and affect the reliability and validity of the results. The reduced sample size in the post-course survey may limit the generalizability of the findings.

CONCLUSION

The use of online professional learning platforms has increased the number of opportunities for teachers who want to further their learning. This study analyzed the effects of a TMYC online professional learning course. Specifically, the study investigates (1) whether participants' beliefs significantly changed and (2) if their pre-course beliefs impacted their engagement in the course. Participant beliefs were measured by the Mathematical Development Beliefs Survey. Results indicated that this study's course significantly and positively impacted preschool teacher's beliefs about the age appropriateness of mathematics and their comfort level with teaching math to young children. Results also indicated that, although not significant, teachers with the most positive initial beliefs completed the course at a higher rate than their peers.

COMPETING INTERESTS

None.

AUTHOR NOTE

Funding: This research was funded by the U.S. Institute of Education Sciences, grant number R305U200001. The information reported in this paper reflects the views of the authors and not necessarily the views of the IES.

Institutional Review Board Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy concerns.

Corresponding Author: Department of Teacher Education and Learning Sciences, North Carolina State University, Raleigh, NC 27695, USA

PROCESSING DATES

09, 2024

This manuscript was initially received for consideration for the journal on 05/09/2024, revisions were received for the manuscript following the double-anonymized peer review on 08/17/2024, the manuscript was formally accepted on 09/13/2024, and the manuscript was finalized for publication on 09/24/2024

REFERENCES

Amador, M. J. F., López, A. D. A., & González, G. J. R. (2023). Didactic contributions of massive open online courses (MOOCs) to mathematics education: A pedagogical proposal for teaching the sine function. *Journal of Hunan University Natural Sciences, 50*(7).

Anderson, A., Huttenlocher, D., Kleinberg, J., & Leskovec, J. (2014). Engaging with massive online courses. In *Proceedings of the 23rd International Conference on World Wide Web*. Publisher. DOI: 10.1145/2566486.2568042

Andrà, C., & Repossi, E. (2018). Engagement in mathematics MOOC forums. *Views and Beliefs in Mathematics Education: The Role of Beliefs in the Classroom,* 11-20.

Archambault, L., Leary, H., & Rice, K. (2022). Pillars of online pedagogy: A framework for teaching in online learning environments. *Educational Psychologist*, *57*(3), 178–191.

Boltz, L. O., Yadav, A., Dillman, B., & Robertson, C. (2021). Transitioning to remote learning: Lessons from supporting K-12 teachers through a MOOC. *British Journal of Educational Technology*, *52*(4), 1377–1393. DOI: 10.1111/bjet.13075

Brennan, K., Blum-Smith, S., & Yurkofsky, M. M. (2018). From checklists to heuristics: Designing MOOCs to support teacher learning. *Teachers College Record*, *120*(9), 1–48. DOI: 10.1177/016146811812000904

Chen, J.-Q., McCray, J., Adams, M., & Leow, C. (2014). A survey study of early childhood teachers' beliefs and confidence about teaching early math. *Early Childhood Education Journal*, *42*(6), 367–377. DOI: 10.1007/s10643-013-0619-0

Chen, W. (2024). Problem-solving skills, memory power, and early childhood mathematics: Understanding the significance of the early childhood mathematics in an individual's life. *Journal of the Knowledge Economy,* 1-25. DOI: 10.1007/s13132-023-01557-6

Clements, D. H., & Sarama, J. (2016). Math, science, and technology in the early grades. *The Future of Children, 26*(2). DOI: 10.1353/foc.2016.0013

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). L. Erlbaum Associates.

Cox, C., Hatfield, T., Moxey, J., & Fritz, Z. (2023). Creating and administering video vignettes for a study examining the communication of diagnostic uncertainty: Methodological insights to improve accessibility for researchers and participants. *BMC Medical Research Methodology*, *23*(1), 296. PMID: 38102577

Darling-Hammond, L., Hyler, M. E., & Gardner, M. (2017). *Effective teacher professional development*. Learning Policy Institute.

DePascale, M., & Ramani, G. B. (2024). Promoting children's mathematical and statistical understanding through parent-child math games. *Cognitive Development*, *71*, 101480.

Dweck, C. S. (1999). *Self-theories: Their role in motivation, personality and development*. Psychology Press.

Dyson, N. I., Jordan, N. C., & Glutting, J. (2011). A number sense intervention for low-income kindergartners at risk for mathematics difficulties. *Journal of Learning Disabilities*, *46*(2), 166–181. DOI: 10.1177/0022219411410233 PMID: 21685346

Elizarov, E., Ziv, Y., & Benish-Weisman, M. (2024). Personal values and social behavior in early childhood: Understanding the contribution of social information processing and attitudes. *European Journal of Psychology of Education,* 1-26.

Farhang, A. P. Q., Hashemi, A. P. S. S. A., & Ghorianfar, A. P. S. M. (2023). Lesson plan and its importance in teaching process. *International Journal of Current Science Research and Review*, *6*(08), 5901–5913. DOI: 10.47191/ijcsrr/V6-i8-57

Ferguson, R., Clow, D., Beale, R., Cooper, A. J., Morris, N., Bayne, S., & Woodgate, M. (2015). Moving through MOOCs: Pedagogy, learning design, and patterns of engagement. In G. Conole, T. Klobucar, C. Rensing, J. Konert, & E. Lavoué (Eds.), *Design for teaching and learning in a networked world: Proceedings from the 10th European conference on technology enhanced learning, EC-TEL 2015* (pp. 70-84). Springer. DOI: 10.1007/978-3-319-24258-3

Findell, B., Swafford, J., & Kilpatrick, J. (Eds.). (2001). *Adding it up: Helping children learn mathematics*. National Academies Press.

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School Engagement: Potential of the concept, state of the evidence. *Review of Educational Research*, *74*(1), 59–109. DOI: 10.3102/00346543074001059

Frye, D., Baroody, A. J., Burchinal, M., Carver, S. M., Jordan, N. C., & McDowell, J. (2013). Teaching math to young children: A practice guide. National Center for Education Evaluation and Regional Assistance, Institute of Education Sciences, U.S. Department of Education., NCEE 2014-4005.

Gerde, H. K., Pierce, S. J., Lee, K., & Van Egeren, L. A. (2018). Early childhood educators' self-efficacy in science, math, and literacy instruction and science practice in the classroom. *Early Education and Development*, *29*(1), 70–90. DOI: 10.1080/10409289.2017.1360127

Hart, S. C., DiPerna, J. C., Lei, P. W., Zhao, H., Sun, T., Li, X., & Husmann, K. (2024). Does universal SEL promote academic success? Examining learner outcomes under routine conditions in first-grade classrooms. *AERA Open*, *10*, 23328584241262746. DOI: 10.1177/23328584241262746

Hollands, F. M., & Tirthali, D. (2014). *MOOCs: Expectations and reality.* Center for Benefit-Cost Studies of Education; Teachers College, Columbia University. https://www.cbcse.org/publications/moocs-expectations-and-reality

Hollebrands, K. F., & Lee, H. S. (2020). Effective design of massive open online courses for mathematics teachers to support their professional learning. *ZDM Mathematics Education*, *52*(5), 859–875. DOI: 10.1007/s11858-020-01142-0

Hunt, J., Duarte, A., Miller, B., Bentley, B., Albrecht, L., & Kruse, L. (2023a). Teacher beliefs and perspectives of practice: Impacts of online professional learning. *Education Sciences*, *13*(1), 68.

Hunt, J. H., Taub, M., Marino, M., Duarte, A., Bentley, B., Holman, K., & Kuhlman, A. (2023b). Effects of game-enhanced supplemental fraction curriculum on student engagement, fraction knowledge, and STEM interest. *Education Sciences*, *13*(7), 646.

Jordan, N. C., Glutting, J., Dyson, N., Hassinger-Das, B., & Irwin, C. (2012). Building kindergartners' number sense: A randomized controlled study. *Journal of Educational Psychology*, *104*(3), 647–660. DOI: 10.1037/a0029018 PMID: 25866417

Kizilcec, R. F., Piech, C., & Schneider, E. (2013). Deconstructing disengagement. In *Proceedings of the Third International Conference on Learning Analytics and Knowledge*. DOI: 10.1145/2460296.2460330

Kowalski, K., Pretti-Frontczak, K., & Johnson, L. (2001). Preschool teachers' beliefs concerning the importance of various developmental skills and abilities. *Journal of Research in Childhood Education*, *16*(1), 5–14.

Lee, J. S. (2006). Preschool teachers' shared beliefs about appropriate pedagogy for 4-year-olds. *Early Childhood Education Journal*, *33*(6), 433–441.

Lee, J. S., & Ginsburg, H. P. (2007). What is appropriate mathematics education for four-year-olds? *Journal of Early Childhood Research*, *5*(1), 2–31. DOI: 10.1177/1476718X07072149

Leijen, Ä., Baucal, A., Pikk, K., Uibu, K., Pajula, L., & Sõrmus, M. (2024). Opportunities to develop student's math-related agency in primary education: The role of teacher beliefs. *European Journal of Psychology of Education*, *39*(2), 1637–1659.

Martín, E. L., & Martinez, D. A. (2023). The effect size in scientific publication. *Educación XX1, 26*(1), 9-17.

Milligan, C., Littlejohn, A., & Margaryan, A. (2013). Patterns of engagement in connectivist MOOCs. *Journal of Online Learning and Teaching*, *9*(2), 149–159. http://jolt.merlot.org/vol9no2/milligan_0613.pdf

Moomaw, S. (2024). *Teaching STEM in the early years: Activities for integrating science, technology, engineering, and mathematics*. Redleaf Press.

National Association for the Education of Young Children. (2009). Developmentally appropriate practice in early childhood programs serving children from birth through age 8 [position statement]. https://www.naeyc.org/sites/default/files/globally-shared/downloads/PDFs/resources/position-statements/PSDAP.pdf

National Association for the Education of Young Children and National Council for Teachers of Mathematics. (2010). Early childhood mathematics: Promoting good beginnings [joint position statement]. https://www.naeyc.org/sites/default/files/globally-shared/downloads/PDFs/resources/position-statements/psmath.pdf

National Mathematics Advisory Panel. (2008). *Foundations for success: The final report of the National Mathematics Advisory Panel*. U.S. Department of Education. https://files.eric.ed.gov/fulltext/ED500486.pdf

National Research Council. (2001). *Adding it up: Helping children learn mathematics*. The National Academies Press., DOI: 10.17226/9822

Onah, D. F. O., Sinclair, J., & Boyatt, R. (2014) Dropout rates of massive open online courses: Behavioural patterns. In *Proceedings of the 6th International Conference on Education and New Learning Technologies*.

Opper, I. M. (2012). *Teachers matter: Understanding teachers' impact on student achievement*. RAND Corporation., DOI: 10.7249/RR4312

Park, M.-H., Dimitrov, D. M., Patterson, L. G., & Park, D.-Y. (2017). Early childhood teachers' beliefs about readiness for teaching science, technology, engineering, and mathematics. *Journal of Early Childhood Research*, *15*(3), 275–291. DOI: 10.1177/1476718X15614040

Platas, L. M. (2014). The Mathematical Development Beliefs Survey: Validity and reliability of a measure of preschool teachers' beliefs about the learning and teaching of early mathematics. *Journal of Early Childhood Research*, *13*(3), 295–310. DOI: 10.1177/1476718X14523746

Polly, D., Mcgee, J. R., Wang, C., Lambert, G., Pugalee, D. K., & Johnson, S. (2013). The association between teachers' beliefs, enacted practices, and student learning in mathematics. *The Mathematics Educator*, 11–30.

Raudenbush, S. W. (2009). The Brown legacy and the O'Connor challenge: Transforming schools in the images of children's potential. *Educational Researcher*, *38*(3), 169–180. DOI: 10.3102/0013189X09334840

Rawlings, B. S., Davis, H. E., Anum, A., Burger, O., Chen, L., Morales, J. C. C., Legare, C. H. (2023). Quantifying quality: The impact of measures of school quality on children's academic achievement across diverse societies. *Developmental Science*, e13434.

Rovai, A. P. (2000). Building and sustaining community in asynchronous learning networks. *The Internet and Higher Education*, *3*(4), 285–297. DOI: 10.1016/S1096-7516(01)00037-9

Shah, P. E., Weeks, H. M., Richards, B., & Kaciroti, N. (2018). Early childhood curiosity and kindergarten reading and math academic achievement. *Pediatric Research*, *84*(3), 380–386. PMID: 29884846

Siegler, R. S., & Ramani, G. B. (2008). Playing linear numerical board games promotes low-income children's numerical development. *Developmental Science*, *11*(5), 655–661. DOI: 10.1111/j.1467-7687.2008.00714.x PMID: 18801120

Siemon, D. (2021). Learning progressions/trajectories in mathematics: Supporting reform at scale. *Australian Journal of Education*, *65*(3), 227–247. https://eric.ed.gov/?id=EJ1320623

Sunar, A. S., White, S., Abdullah, N. A., & Davis, H. C. (2016). How learners' interactions sustain engagement: A MOOC case study. *IEEE Transactions on Learning Technologies*, *10*(4), 475–487. DOI: 10.1109/TLT.2016.2633268

Venter, A. (2024). Exploring the downside to student online collaborations. *The Independent Journal of Teaching and Learning, 19*(1), 64-78.

Vivian, R., Falkner, K., & Falkner, N. (2014). Addressing the challenges of a new digital technologies curriculum: MOOCs as a scalable solution for teacher professional development. *Research in Learning Technology, 22*. DOI: 10.3402/rlt.v22.24691

Whitehouse, P., Breit, L., McCloskey, E., Ketelhut, D. J., & Dede, C. (2006). An overview of current findings from empirical research on online teacher professional development. In Dede, C. (Ed.), *Online professional development for teachers: Emerging models and methods* (pp. 13–30). Harvard Education Press.

Wilkins, J. L. (2008). The relationship among elementary teachers' content knowledge, attitudes, beliefs, and practices. *Journal of Mathematics Teacher Education*, *11*(2), 139–164. DOI: 10.1007/s10857-007-9068-2

Wu, M. Y. H., Alexander, M. A., Frydenberg, E., & Deans, J. (2024). Early childhood social-emotional learning based on the Cope-Resilience program: Impact of teacher experience. *Issues in Educational Research*, *30*(2), 782–807.

Yu, Z., Xu, W., & Sukjairungwattana, P. (2024). A meta-analysis of eight factors influencing MOOC-based learning outcomes across the world. *Interactive Learning Environments*, *32*(2), 707–726.