Connect4Learning™

Connect4Learning: The Pre-K Curriculum

Interdisciplinary Teaching Across Domains

Introduction

Connect4Learning (C4L) is an interdisciplinary early childhood curriculum, the development of which was funded by the National Science Foundation. C4L aims to synthesize research-based approaches in four domains of learning: mathematics, science, literacy, and social-emotional development. The curriculum uses an interdisciplinary approach to address growing concerns that the majority of preschool instructional time is devoted to literacy at the expense of other content areas, particularly mathematics and science. The C4L research team is composed of nationally recognized experts in early childhood education: Julie Sarama, Kimberly Brenneman, Douglas H. Clements, Nell K. Duke, and Mary Louise Hemmeter. This team followed an intensive research and development framework to guide the curriculum's development, which resulted in six instructional units for pre-kindergarten children and their teachers. This paper identifies the developmental and educational needs addressed by C4L, outlines the program's three phases of development, highlights the curriculum's structure, and proposes future avenues of exploration.

Addressing Needs in Early Childhood Education

False Dichotomies

False dichotomies and fierce debates often plague the field of early childhood education. Play versus academics is perhaps the most widely cited example, with the implication being that they are mutually exclusive. Many educators and parents prioritize the development of social-emotional skills such as following directions, getting along with others, and working together in the early years over academic learning. They argue that sequenced and intentional academic instruction will have a negative impact on children's social-emotional development, creativity, and play. These concerns are unfounded, however, as studies reveal that learning in the academic areas of math and literacy are related to each other and to play. Research shows that children naturally explore and engage with content areas such as mathematics during their free play (van Oers 1996). For example, children will, without prompting, count their toys and their snacks, and they will attend to shapes and form while building with blocks. Indeed, in nearly half of all the minutes that children engage in free-choice play, they are engaged in mathematics (Seo and Ginsburg 2004). Further, we have long known that play provides a rich context for literacy and language development (Galda and Pelligrini 2014; Neuman and Roskos 1992). Preschools that do either math or literacy instruction show increases in the quality of young children's play (Aydogan et al. 2005). The frequently held belief that preschoolers will not benefit from the specific teaching of mathematics, science, and literacy is unfounded (Clements and Sarama 2009). The research evidence suggests that high-quality instruction and high-quality free play do not have to compete for time in the classroom. Doing both well makes each one richer.

Content Area Debates

Additional debates focus on specific content areas, particularly the question of how much attention math versus literacy should receive in the classroom. Meanwhile, science is rarely mentioned, let alone prioritized in practice (Cervetti et al. 2006). It is established that math and science proficiency in the United States is low in comparison to other developed countries, and that within the United States, the achievement gap is even wider for children who live in poverty and are members of linguistic and ethnic minority groups (Denton and West 2002; Ginsburg et al. 2005; National Research Council 2001, 2007, 2009). The origins of these achievement gaps begin in early childhood when children from low-income families already possess less extensive math and science knowledge than middle-income children due to fewer high-quality math and science learning opportunities at home and at school (Blevins-Knabe and Musun-Miller 1996; Brenneman, Massey, and Metz 2009; Holloway et al. 1995; Jordan, Huttenlocher, and Levine 1992). These gaps are widening, and knowledge of scientific understanding is emerging as a particular concern. Research finds that among the eight Head Start Learning Outcomes, children entered kindergarten with lower science readiness scores than in any other domain (Greenfield et al. 2009). The evidence is clear that early childhood curricula must address the low level of achievement in both math and science with special attention to at-risk populations.

Children are ready and eager to learn, but many early childhood educators are not equally prepared to engage them in the rich math and science experiences that lay the groundwork for later success in school and career (Brenneman, Stevenson-Boyd, and Frede 2009; National Research Council, 2001, 2009; Sarama and Clements 2009). Observational studies reveal that full-day, literacy-based curriculum may include only 58 seconds of mathematics instruction per day (Farran et al. 2007). Studies suggest a similar trend with science, finding that teachers spend minimal time engaged in either planned or spontaneous science-related activities. Even in classrooms with a dedicated science table, neither teachers nor children spend much time actively engaging with available science content (Nayfeld, Brenneman, and Gelman 2012; Tu 2006). Science instruction often consists of very simple and isolated activities, giving young children limited opportunity to engage in the experiences and develop the skills necessary for future science learning. This lack of meaningful math and science instruction in the preschool years means that school readiness in these important domains, particularly among underserved populations, is unlikely to improve. Language and literacy and social-emotional development certainly must be supported during the early childhood years (Jones, Greenberg, and Crowley 2015). However, what remains open for consideration is the question of whether emphasizing these areas necessarily requires less emphasis on other important domains, particularly math and science, or whether multiple domains can be effectively combined to address time competition in the preschool classroom.

In contrast to math and science, literacy receives considerable attention in the preschool classroom. However, this attention relies heavily on instruction in letters and sounds, which is certainly important but not sufficient. Literacy research is robust and reveals there are many important contributors to the ultimate goal of reading comprehension, including receptive and expressive language, vocabulary, inferencing skills, and concept and world knowledge. Similarly, although alphabet knowledge and phonological awareness predict later reading comprehension ability, so do expressive and receptive language comprehension skills and vocabulary knowledge (Lonigan, Schatschneider, and Westberg 2008; Nation and Snowling 2004). Therefore, there is a growing argument that foundational literacy skills should not be addressed at the expense of language and content knowledge (Duke and Carlisle 2011; Hirsch 2003). Rather, researchers are increasingly arguing that world knowledge, in addition to word knowledge, is essential for constructing meaning from text. Unfortunately, current classroom practice does not foster the full range of knowledge needed for successful reading. Children are provided with very little exposure to, or experience with, informational and expository text in early childhood (Duke, Bennett-Armistead, and Roberts 2003; Pentimonti, Zucker, and Justice 2011). Although storybook read-alouds are frequent, informational read-alouds are rare.

Similarly, while children may be encouraged to dictate stories, they are rarely invited to dictate informational text. As is often the case, children from lower-income communities face this disparity the most. They are even less likely to be provided with opportunities to interact with informational text in school, just as they are less likely to have opportunities to develop content area knowledge (Halvorsen 2003; Sarama and Clements 2009). These same children are also substantially less likely to meet performance expectations in informational reading (Park 2008). C4L may be an important step toward reversing this trend through offering significant opportunities for informational reading and writing in the context of math and science learning experiences.

C4L Addresses Concerns

The C4L approach is inspired by and extends from the above research findings. In particular, C4L recognizes the following: a) play and academic instruction can work synergistically in early childhood, b) early academic skills are essential to later school success, c) current approaches to early education too often provide superficial math and science experiences that neither support the richness within these domains nor the interconnectedness between them, and d) a more multifaceted and intentional approach to social-emotional, language, and literacy development and language and literacy learning is critical to school readiness. C4L demonstrates how all four domains can be developed and supported through focused math and science experiences. The C4L approach also addresses educator concerns that they do not have sufficient time to teach math and science because of other school requirements (Greenfield et al. 2009; Sarama and Clements 2009). To address this concern, C4L departs from the usual curriculum development strategy of building the curriculum around literacy. Instead, the C4L units build on a sequence of math and science topics that are grounded in research-based learning trajectories and developmental pathways. Literacy and social-emotional skills are developed in the context of these math and science topics, as well as through focused lessons.

Developing the C4L Curriculum

The Curriculum Research Framework (Clements 2007) guided C4L's development. This section explores the three categories of this rigorous research and development process.

Category 1: Strong Foundations

The first category of development included grounding the C4L curriculum in research by reviewing philosophies, theories, and empirical results on learning and teaching across all domains. Principal investigators analyzed research and consulted with experts to identify appropriate goals and objectives that would make a substantial contribution to young children's learning (Sarama 2004; Sarama and Clements 2008). Principal investigators also reviewed empirical findings detailing what makes early childhood instruction particularly effective and motivational, which ultimately facilitated the creation of general guidelines for classroom learning activities. In addition, the C4L authors' previous projects followed this same approach of building on foundational research and helped to form the basis for the C4L components as identified below.

Mathematics: Learning Trajectories

Learning trajectories and teaching approaches developed with National Science Foundation support resulted in a research-based math curriculum for preschoolers that addresses the domains of number and quantity, and geometric and spatial reasoning, including measurement (Clements 2007; Sarama and Clements 2008). Woven throughout these core areas are mathematical subthemes such as sorting, sequencing, and patterns, often referred to as children's mathematical building blocks. The learning-trajectories approach finds the math within children's natural activity and extends it through the use of engaging stories, informational texts, and games. Curriculum lessons are based on children's experiences and interests with an emphasis on supporting mathematical thinking and reasoning. Recent studies (Clements et al. 2011; Sarama and Clements 2009) indicate the power of the learning-trajectories approach for math achievement, with especially promising results not only in mathematics performance but also on oral language scales.

Science: Connected Science Learning Experiences

To best support science learning, curriculum planning should identify and support a few core ideas that are addressed through classroom learning experiences (National Research Council 2007). In preschool, however, science-learning experiences are rarely offered, and when they are, they are all too often stand-alone activities that do not foster deep engagement and learning. Developed by preschool educators and developmental psychologists, Preschool Pathways to Science (PrePS) is a science-based curricular planning framework that is rooted in learning theory and encourages children to think critically about a particular science concept for an extended period of time (Gelman et al. 2010). Curriculum planned with the PrePS approach incorporates science practices that children use repeatedly across content areas, including observing, predicting, comparing, contrasting, and experimenting (Gelman et al. 2010). C4L incorporates elements of PrePS and other high-quality, standards-aligned science approaches by providing opportunities for children to practice inquiry skills through deep engagement with science concepts; by engaging children in life science, physical science, earth and space science, and engineering; and by incorporating mathematics and literacy as critical to the scientific endeavor.

Language and Literacy: Authentic Literacy

Authentic literacy (Purcell-Gates et al. 2002; Purcell-Gates, Duke, and Martineau 2007) involves reading and writing texts for the same purpose within school as outside of school. Reading is primarily for the purpose of learning information, enjoyment, and to accomplish specific tasks, rather than simply to learn literacy skills such as decoding and acquiring vocabulary. Studies show that students who are exposed to more authentic literacy activities grow at a higher rate in reading and writing of informational and procedural text in science (Purcell-Gates, Duke, and Martineau 2007). Research also finds that incorporating authentic literacy into curriculum planning, such as writing in science journals, is educational and meaningful for preschoolers (Brenneman and Louro 2008; Gelman et al. 2010).

Social-Emotional Development: The Pyramid Model

The Pyramid Model for Promoting Social-Emotional Competence (Fox et al. 2003; Hemmeter, Ostrosky, and Fox 2006) provides guidance for early childhood educators on the use of effective, research-based instructional practices (Brown, Odom, and McConnell 2008; Burchinal et al. 2010; National Research Council 2001) and behavior supports for all children, including those with severe behavioral challenges (Blair, Fox, and Lentini 2010; Conroy, Dunlap, Clarke, and Alter 2005; McLaren and Nelson 2009). The *Pyramid* is a framework of practices rather than a specific curriculum. As such, it can be seamlessly integrated into an interdisciplinary curriculum with an adaptive approach that is uniquely tailored to the characteristics of the context and individual needs of the children within that setting.

Category 2: Lesson and Project Development

In the second category of the Curriculum Research Framework, principal investigators designed research-based curriculum lessons in the targeted domains. According to this model, learning trajectories should be interwoven within and across domains, rather than taught in separate curricular units for five distinct reasons. First, children's learning is continuous and incremental (Clements and Sarama 2007; Siegler 1996). Second, the learning within each domain cover years of child development, which makes adequate compression into units difficult. Third, the early childhood years are a time of substantial cognitive growth and development, with wide individual differences (National Research

Council 2001); therefore, distributing opportunities to learn topics across the year is more effective. Fourth, across all ages, distributed practice yields better recall and retention of content (Cepeda et al. 2006; Rohrer and Taylor 2006). Finally, interweaving domains may facilitate mutual reinforcement between learning trajectories (Clements and Sarama 2007).

During this phase of development, the C4L principal investigators designed unit projects that incorporated all domains, and developed integrated instructional lessons when appropriate. Their strategy was to begin with mathematics for which there is an established research-based developmental scope and sequence (Clements and Sarama 2009; Sarama and Clements 2009) and then determine meaningful connections to science. Math and science units incorporated language and literacy competencies, informed by the learning trajectories and developmental pathways that govern those domains, such as phonemic awareness and letter recognition. Finally, principal investigators referred to pedagogical strategies known to enhance social-emotional development when designing the instructional activities. This approach emphasized three key areas: 1) designing the learning environment to promote children's engagement with activities, materials, and peers; 2) supporting the development of children's social skills and emotional competencies, particularly self-regulation; and 3) implementing a planned and intentional approach to preventing and addressing challenging behavior (Fox et al. 2003; Hemmeter, Ostrosky, and Fox 2006).

Category 3: Formative Evaluation

In the third category, principal investigators collected empirical evidence to evaluate the appeal, usability, and effectiveness of the C4L curriculum and to engage in repeated cycles of creative rewriting and refinement. They worked intensively with selected teachers at three research sites. This early pilot data revealed that C4L shows promise for young children's learning. Children in classrooms that implemented the C4L curriculum with integrity significantly outperformed children in a comparison group on measures of math, literacy, vocabulary development, science, and social-emotional learning, including number sense, early geometry skills, vocabulary knowledge, and name writing.

Visiting a C4L Classroom

Visiting a C4L classroom provides additional evidence of how the research behind the curriculum is put into practice. Unit 2, "We Care About Our Environment" has a heavy emphasis on math and science, as with all of the C4L units. The focus of Unit 2 is learning about the people, plants, animals, and earth features of the local environment; learning about the connections and interdependence among those parts; and contrasting this with the high-interest environment of a coral reef. Children transform their classroom into a coral reef and engage visitors in a scavenger hunt of the reef environment as the unit's central project. This project integrates math, science, literacy, and social-emotional development, as well as emphasizing fine motor control, visual arts, and music, among other domains.

From informational texts, discussion, and exploration, children learned a variety of important science concepts, such as how to reduce, reuse, and recycle, and how to sort materials for recycling as ways to care for their local environment. In the social-emotional domain, the theme was social problem solving. Four distinct steps were taught to reinforce this theme, 1) identifying the problem; 2) thinking of solutions; 3) evaluating solutions; and 4) trying a solution, such as waiting and taking turns, saying "Please stop," or getting a teacher. In the language and literacy domain, children gained practice recognizing the first letters in their names, reading about their environment, and clapping syllables through the use of authentic literacy activities.

Within the math domain, curriculum lessons focused on number and geometry. Children learned counting-based finger plays, read counting books, played counting games, and practiced writing numerals. The selected books and games incorporated multiple skills beyond basic counting, including an emphasis on early literacy, social-emotional growth, and fine motor development. Board games and card games are introduced through all the C4L units. The intent is for children to learn how to play a game, roll dice, count spaces, and take turns. By the end of this unit, children had practice counting forward to ten and backward from ten, as well as naming numerals up to nine. In geometry, children learned to match congruent shapes, identify shapes by name, find shapes in their environment, and compare and classify shapes. Children also learned about shapes' properties and constructed shapes from their component parts. Across the C4L math activities, teachers consistently ask children, "How do you know?" a process that promotes deep mathematical and scientific thinking and social-emotional development.

C4L: An Interdisciplinary Curriculum

The three-category research and development model outlined above resulted in the current *Connect4Learning: The Prekindergarten Curriculum*, featuring an interdisciplinary approach with process goals that are common to all four domains of learning. The interdisciplinary character of C4L manifests itself in four ways:

1. Consistent approach to instruction in each domain that includes responsive teaching, use of appropriate tools, iterative learning cycles with reflection and practice, and project-based learning.
2. Common topics across disciplines.
3. Lessons and learning experiences simultaneously addressing objectives from different disciplines.
4. Interactions and experiences in all domains that address the same core set of thinking processes.

C4L is organized into six units of instruction with culminating projects that incorporate and build upon skills from all domains. In order of implementation, these six units include:

1. Connecting with School and Friends
2. Our Environment
3. How Structures Are Built
4. Exploring Museums
5. Growing Our Garden
6. How We've Grown

C4L Processes

C4L develops cognitive processes that are both domain specific and applicable across all four domains. Table 1 identifies the ten C4L process goals, with examples of relevant classroom skills.

Table 1: C4L Processes

Process	Preschool Skills
1. Communicating and Representing	• Develops clarity and precision • Includes beginning modeling • Writes for various purposes • Communicates findings, explanations, and reflections
2. Cooperating	• Plans, initiates, and completes learning activities with peers • Joins in cooperative play • Models or teaches peers • Helps, shares, and cooperates in a group
3. Comparing and Classifying	• Compares characteristics of objects • Notes similarities and differences • Sorts and classifies by one or more attributes • Compares quantities
4. Creating, Imagining, and Innovating	• Creates products • Thinks flexibly
5. Curiosity—Asking Questions and Seeking New Information	• Investigates problems • Explores new topics • Seeks in-depth learning
6. Observation	• Uses senses to process information • Describes observations accurately • Writes, draws, and labels observations
7. Persisting, Attending, and Self-Regulation	• Demonstrates executive control • Maintains focus and attention • Shows independence • Listens with understanding
8. Reasoning and Problem Solving	• Uses the scientific method • Seeks multiple solutions to a question, task, or problem • Makes inferences • Engages in trial and error • Connects the new to the known • Uses evidence to reach conclusions
9. Seeking to Make Sense	• Thinks interdependently • Demonstrates strategic thinking • Coordinates evidence and experience to generate explanations • Understands patterns and structure
10. Using Tools Strategically	• Uses tools to investigate mathematical concepts • Uses tools to investigate scientific phenomena • Uses text to achieve purposes

The C4L curriculum incorporates all processes within each unit, but some units place a stronger emphasis on a particular process goal. Table 2 provides a scope and sequence to demonstrate how the ten C4L learning processes are addressed within and across the curriculum.

Table 2: Scope and Sequence—Processes across the C4L Curriculum

Process	C4L Unit					
	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
1. Communicating and Representing	X	X	X	X	X	
2. Cooperating	X	X		X		
3. Comparing and Classifying	X	X	X	X	X	X
4. Creating, Imagining, and Innovating	X	X	X	X		
5. Curiosity—Asking Questions and Seeking New Information		X		X		
6. Observation	X				X	
7. Persisting, Attending, and Self-Regulation	X	X	X	X		
8. Reasoning and Problem Solving	X	X	X	X	X	X
9. Seeking to Make Sense		X	X	X		X
10. Using Tools Strategically	X		X	X		

Toward the Future: Professional Development

Training teachers to implement a new curriculum in one domain can be challenging. Implementing and integrating four domains of learning can be daunting. Professional development for the C4L Pre-K Curriculum should include a) professional learning in research-based instruction within each of the four C4L domains; b) professional learning about interdisciplinary and project-based instruction; c) professional learning about the specific structures of the C4L curriculum (such as Fast Focus and learning centers); and d) ongoing coaching to foster effective implementation of the curriculum. With these important goals in mind, the C4L principal investigators will continue to work to inform the design of innovative professional development to complement the C4L curriculum and ensure that all young children have the opportunity to reach their highest potential.

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