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RESEARCH ARTICLE

Building computer supported collaborative learning environments in early childhood classrooms

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Abstract
A Multi-touch table functions as a tablet, but allows multiple children to move around and manipulate the screen simultaneously. Using social cognitive theory (Bandura 1997) to analyze group dynamics, this study examined computer-supported collaborative learning. Children were observed and recorded for 20 min, three times a week for 5 weeks as they manipulated apps developed by Kaplan Early Learning Company for the multi-touch table Engage-2. Results indicate that the ability of multiple children to manipulate an app simultaneously encouraged collaboration while issues of personal space were rarely present. Multiple problem-solving strategies were in evidence as the children manipulated the apps. Results suggests that individual agency turned into collective agency during the app play.

Keywords Technology · Early childhood · Computer supported learning environments

The foundation of early childhood education is Developmentally Appropriate Practice (DAP), a concept that brings together knowledge of child development, the development of the individual child, and the culture of the child (Copple et al. 2009). As with other classroom materials, it is critical that technology is incorporated into the classroom using DAP (Rosen et al. 2009). The National Association for the Education of Young Children NAEYC (2012) divides technology in the early childhood classroom into passive (e.g. television) and interactive (e.g. tablets) technologies. Interactive technology includes digital media that engages the young child in active learning as she interfaces with the device. The Fred Rogers Center (2012) provides two principles for digital media use: (a) "quality digital media should safeguard the health, well-being, and overall development of young children, and (b) quality in digital media for young children should take into account the child, the content and the context of use" (p. 6). These principles support DAP through intentional use of technology in the classroom. After a 5 year study reported out of the Fred Rogers Center, Paciga et al. (2017) found that using a play-based, whole child approach

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results in supporting a young child's social-emotional development when the technology or software is designed for social interaction.

The International Society for Technology in Education [ISTE] includes early childhood in their technology standards. The 2016 ISTE Standards for Pre-K-12 students emphasizes fitting technology into pedagogy rather than focusing on the technology as a tool (ISTE-S 2016). The ISTE Student Standards (International Society for Technology in Education 2016) and the NAEYC technology statement (2012) share an emphasis on appropriate pedagogy, collaboration, and understanding technology use. ISTE-S (2016) provides a framework for developing intentional and appropriate classroom interactions with digital technology for young children. Foundations are built for young children to become Technology Literate Students (ISTE 2016) in the areas of active learning, and social outcomes through communication and collaboration. As digital technology becomes more prevalent in education settings, early education teachers need to focus on introducing and extending technology in preparation for the child to become a Technology Literate Student.

Technology use in early childhood education is a divisive issue (NAEYC 2012), a fact reflected in research. Several studies link numerous negative impacts to screen time including child obesity, increased aggression, and impediments on social development (Armstrong et al. 2000; Birch et al. 2010; Romeo et al. 2003; White House Task Force on Childhood Obesity 2010). In contrast, other research indicates positive academic and social outcomes when children use technology (Couse et al. 2010; Garvis 2016; Wolfe et al. 2013). While the Fred Rogers Center and NAEYC (2012) stress that digital technology has a role in the early childhood classroom, the technology statement notes concerns from early childhood educators about the potential for inappropriate use and for unequal access due to income disparities (and location if the child lives in a rural area).

A major concern involving technology, specifically personal computers and tablets, in early childhood classrooms (NAEYC 2012) is a possible decrease in social engagement between children. A new technology in early childhood classrooms, the multi-touch table, is emerging that is designed to foster group collaboration to develop a computer supported collaborative learning (CSCL) environment. CSCL environments allow individual and collaborative learning between learners (Gress et al. 2010). In a meta-analysis of effects of CSCL, (Chen et al. 2018) report that CSCL environments resulted in positive effects on knowledge gain, skills acquisition, and student computer use. The studies selected for the meta-analysis did not focus on early childhood classrooms, but young children can begin to build knowledge about CSCL environments found in older classrooms. In this study we examine what a CSCL foundation might look like in an early childhood classroom while manipulating multi-touch technology.

The multi-touch table's size and multi-user interface allows the young child to move and play around the table while interacting with other children, potentially answering concerns about decreased social engagement and physical activity. For young children, multi-touch technology provides an opportunity to build skills that are foundational to a CSCL. Using a multi-touch table to assist in creating foundational skills such as group collaboration around a shared goal within a CSCL environment is new in early childhood environments and there is scant research into how their current use in classrooms may affect the learning and social process (Jackson et al. 2013; McEwen et al. 2015). This study adds research knowledge through an exploratory, qualitative research design that examines group dynamics and collaboration within a CSCL context using a social cognitive theoretical framework.

Theoretical framework and research questions

Social cognitive theory posits that one way learning occurs is through collective agency, involving interactive and coordinated dynamics on the group level. Individual acts within a given social environment results in a co-creation of experiences and goals (Bandura 1997). One way to connect social cognitive theory to technology use by young children is to examine how collective agency might be built through computer-supported collaborative learning environments. The interactive digital activity could affect the nature of collaboration and aid in building the beginnings of a CSCL environment.

This research project recorded young children as they manipulated an Engage-2 multi-touch table. A qualitative approach allowed the researchers to explore social/emotional dynamics using social cognitive theory as a base within a technology-based classroom context. These questions guided the study:

- What is the nature of child-to-child interactions during utilization of the multi-touch table?
- How does the multi-touch table foster social learning and collective agency?
- How do children demonstrate active social outcomes and technology competence, as defined by ISTE and NAEYC?

Literature review

Interactive technologies

Computer-based technology in the early childhood classroom began with the desktop, keyboard, and mouse. The learning context involved a single child controlling the mouse/keyboard/touchscreen, thus engaging in a solitary activity. Early studies using the child-desktop context (Armstrong et al. 2000; Romeo et al. 2003) found that children's use of technology negatively impacted social development. A CSCL environment was not present. Tablet technology followed the desktop and offered the potential for two or three children to sit around the tablet as they worked together. Recent research (O'Mara et al. 2011; Wolfe et al. 2013) found that children do collaborate and work together with tablet technology, although limited due to contextual constraints. The contextual constraints present with a tablet include orientation of the display and single-user touch-screen control. Interactive whiteboards with features that could promote collaboration, are often used by teachers for large group instruction with children as observers (Rick et al. 2009).

Research is increasing on the use of the multi-touch table in the classroom. (Mercier et al. 2016) reported that students in a multi-touch classroom engaged in more task-focused talk while working in a non-traditional forward-facing room arrangement. Bause et al. 2018 utilized collaboration support kits with multi-touch technology and found that students engaged in more robust discussion. (Jackson et al. 2013) report that teacher training is critical and that the multi-touch table needs to be present in the classroom so that children are familiarized with the new device. Rick et al. (2009) suggest that multi-touch technology avoids the problem of the single-user technology by creating "shareable interfaces" (p. 321) for small group learning. Results from one research study (Gu et al. 2017) suggests that within a CSCL, collaborative roles are influenced by cultural factors. When

specifically exploring the commonly held beliefs that associate technology's use with social isolation and sedentary behaviors (Plowman et al. 2012) early childhood professionals found that children's tablet play was active, joyful, cooperative, and collaborative (Shifflet et al. 2012). Potentially, digital literacy is built not by the isolated individual, but within a group as the screen is simultaneously manipulated. The child's individual agency may transform into collective agency.

Prosocial learning: cooperation, collaboration and communication

Social interaction is inextricable from emotional development (Bandura 1977). Opportunities for social learning vary and peer-to-peer interaction provides opportunities to learn skills of social problem solving that cannot be duplicated in adult–child relationships or in isolation. Clearly, in order to learn how to get along with others, one has to *be* with others in multiple settings over extended periods of time. While studying traditional play-based learning, Robson reported that self-regulation skills were more prevalent in child-initiated activities rather than adult-initiated ones in traditional play-based learning (Robson 2016). Multi-touch tablet play is intrinsically child—initiated play. Social interaction and collaboration take on new meaning when viewed through the lens of technology. Cicconi (2014) found that collaborative tools such as *VoiceThread* were ideal for assisting young learners with mathematics concepts in ways that were not duplicated with traditional methods. Moore et al. (2015) described similar collaborative play strategies while comparing pre-service teachers' and preschoolers' uses of open-ended apps. Using home settings as their research context, McPake, Plowman and Stephen (McPake et al. 2013) found that virtual tools were widely used and were effective in fostering communication among families. By carefully choosing the media and providing a supportive environment, digital tools can play a vital role in the development of social skills including peer-assisted learning (NAEYC 2012).

Social conflict and resolving problems

When children interact, conflict inevitably emerges. Similar to learning cooperation and communication, skills associated with solving problems (whether technical or social) are a part of the overall fabric of young children's development. Children need "prosocial skills to manage a conflict that results in a mutual solution" (Riley et al. 2008, p. 47). Learning to solve problems with peers is a long-standing priority in early childhood education (Copple et al. 2009; Ho et al. 2018). Problems arise instantaneously and frequently during the use of interactive technology. Whether the problems are of a social nature (turn-taking, interrupting play, stopping to instruct,) or technological (learning game roles, app manipulation, device shutdown), children apply their current problem-solving skills to the situation. Methods for solving problems occur within a social context and just as in other social situations, some skills are more effective than others. The swift pace of interactive technology could add to the pressure to solve problems quickly. In order to build skills in problem-solving, children need experience and guidance from supportive adults. Mawson (2013) found that 3- and 4 year-olds were able to solve technological problems. "Confidence grows when children have the opportunities to solve problems" (Willis and Schiller 2011, p. 43). Interactive technology provides those opportunities.

Sense of self and self-efficacy

Developing a sense of self includes multiple elements and complex psychological processes. A growing sense of initiative and intentionality is one part of this process. Effective preschool education assists children to gain a sense of self-efficacy, as described in current learning indicators (Office of Administration for Children and Families 2015).

Cause and effect, actions and reactions, observation and experimentation- all are central to children's growing sense of being active participants in the world around them. The responsive nature of interactive media is particularly suited to building participants' confidence in their abilities and control over their own learning. Apps are often designed with built-in consequences for actions: verbal responses such as "You did it!" or "Try again"; sound effects and visual cues; or satisfactory task completion, such as assembling parts of a virtual insect and seeing it fly. The ease of touch-screen technology can even enable successful active experiences with toddlers (Geist 2014). As children experience instant feedback they can adjust their actions accordingly. Selecting technology that allows for trial and error affirms the importance of the *zone of proximal development*, in which learning is maximized (Vygotsky 1978). Children, just as adults, can be quite self-confident without also having a sense of self-efficacy that is rooted in reality. Experimenting with technological tools that provide feedback could provide children with realistic pictures of their abilities, thus encouraging initiative designed to extend their learning.

Methods

Setting

This research occurred in the lab school at a teaching university in New England, and received Institutional Review Board approval. The lab school runs several programs including a full-day preschool with 18 children in which the research occurred. Two lead teachers and one part-time teacher participated in the study, and a number of work-study students were present during filming. The 18 child participants' age range was 2.5–5 years and the group consisted of 14 boys and 4 girls. (Table 1) An Engage-2 multi-touch table was located in a classroom annex that also contained art, reading, and sensory centers. The table was available to the children during morning center-time and during late afternoon individual choice-time. Children self-selected table play and there was no attempt to balance or direct participation by age or gender.

Tools and procedures

The Engage-2 multi-touch table was delivered to the researchers 6 weeks prior to the data collection period. Researchers spent 4 weeks acclimating to the table, including the use of Kaplan Early Learning Company's preloaded apps. The Kaplan pre-loaded apps were reviewed by the researchers for use based on the following criteria (Travers and More 2013): (a) designed to encourage strong levels of social and cognitive engagement, (b) followed Developmentally Appropriate Practice, (c) accessible to all learners, and (d) promoted interaction between the children. Four apps Math Bubbles, Group Bubbles, Puzzles and Insect Creator, were selected for use during the video sessions based on the app

Table 1 Participants by age, gender and frequency of participation

Child	Age/gender	Number of sessions
Gary	5/M	12
Felipe	5/M	7
Lucy	4/F	7
Jerry	3/M	7
Sam	5/M	6
Abel	4/M	6
Twyla	3/F	6
Kendall	4/M	4
Bobby	4/M	3
Jules	4/M	3
Sherry	3/F	2
Ivan	4/M	2
Ali	5/M	2
Ricky	3/M	1
Wills	2/M	1
Danny	2.5/M	1

Pseudonyms

criteria and the Teacher Feedback Surveys. During the last week of the study 1 additional app, Math Sentences, was made available to stimulate interest. This design permitted targeted observations of the interactions between apps and child interactions. Math Bubbles and Group Bubbles allow children to drag and place items (i.e. numbers, pictures) into bubbles. New bubbles can be created, separated, or popped by using the figure *Penelope*. In Puzzles, children put together puzzles from pictures or short videos. Teachers can adjust the number of puzzle pieces and difficulty level. Insect Creator allows children to build insects by dragging specific body parts that are then placed together. The insect parts and insects once built move on the screen. In Math Sentences, children are provided with a target number and then must create a math sentence that equals the target. A resident frog that sits on a log rewards correct answers or prompts children to try alternate solutions. (K. Elmore, Personal Communication, January 7, 2016).

The researchers conducted in-service training for preschool staff on the use of the multi-touch table. After the training, children were introduced to the table during a two-week period in the classroom. At the end of each day, teachers completed a short Teacher Feedback Survey that focused on technical and social issues that arose as the multi-touch table was introduced to the children. This Survey was designed to contribute daily teacher feedback to the researchers and the information provided was one of the criteria used to select the four apps used by the children during the 5 weeks of observation. Feedback surveys and policies were reviewed by the lead researcher and minor adjustments were made to research procedures.

Videos and the accompanying transcripts were primary data sources. Additional data were collected through Teacher Feedback Surveys and Observation Notes. At the end of the 2 weeks of training, the researchers began data collection, using their individual tablets to record the children for 20 min, three times a week for 5 weeks as they played with the pre-loaded Kaplan apps. The recordings occurred on the same days and times of the week.

Some brief interruptions in filming resulted in 18 video recordings. Researchers rotated responsibilities for recording a session and for posting observation notes, videos and transcripts using a shared interactive platform. Each researcher viewed all videos and independently created transcripts.

Qualitative research must be guided by a transparent process of study design, including consistent methods of data collection and analyses, e.g. transferability and trustworthiness (Lincoln et al. 1985). This study demonstrated transferability through initial, shared teacher training, extended acclimation period of tool's use to reduce any novelty effect, and detailed and clear study design. The study addressed trustworthiness through: independent review, transcription of transcripts, and creation of preliminary categories by each researcher; and collaborative discussions to refine categories of meaning.

Data analysis

The researchers individually examined all 18 transcripts for common meanings through multiple readings. Preliminary analysis included: individual researcher highlights/notes on consistent patterns of participation or interactions; notation of unique or notable incidents; identifying actions, language and skills related to group dynamics and/or technology use; and individual children's impact on technology and play patterns.

During the data collection period, researchers met informally to discuss preliminary findings (Castle 2012). At that time, researchers shared their ideas for clusters of meanings, based on common language, demonstrated skills, or interactions (Creswell 2012). As analysis continued, researchers returned to earlier transcripts to refine categories and note new developments based on the totality of the data. This procedure permitted researchers to identify any changes over time as children became more acclimated to the tool and apps, as well as provided accurate depictions of the fluid nature of small group formation over the study's duration. For example, the interaction of particular apps and accompanying types of child interactions became more marked as the study drew to its conclusion.

After data collection ended, researchers met on numerous occasions to compare their rough groupings, collapse and combine those groupings into clusters of meaning (Castle 2012), and review data for any unexpected or unique findings. Problem-solving, for example, emerged in both researchers' observations and analyses as a thread connecting individual video sessions. This recursive process of analysis, discussion, and expanded analysis (Creswell 2012), resulted in the organization of data into categories of meaning that related to the research questions (Hatcher and Squibb 2011).

Results

Child participation by age and gender

The open-ended design of the study allowed free-choice by the children on their use of the table, the amount of children playing at one time, and the duration of their play. Participation by age and gender was not a purpose of this study although some differences were noted anecdotally during data collection. Due to the uneven composition of the sample, (See Table 1) any interactions of age and gender with social interactions and problem-solving are reported in descriptive format only.

Sixteen of the 18 eligible children played with the multi-touch table for one or more sessions during the data collection period. Thirteen of fourteen males engaged in tablet play, and three of the four females. Gary, a 5 year old male, was the most consistent participant, using the Table 1 of the 18 sessions, often playing during an entire 20 min filming session. Of the three females who used the table, 4-year-old Lucy participated actively in seven sessions, while 3-year-old Twyla engaged briefly in six sessions. Most sessions were dominated by males and older children. Of the seven most frequent users, five were male. Six children used the table only 1 or 2 times (Table 1) Consistent with developmental expectations and as documented in anecdotal evidence, younger participants exhibited less sophisticated problem-solving skills than older participants.

Child-to-child interactions

Characteristics of play and playgroups

Children's play was physically active and verbal. Sessions were typically noisy and energetic and play flowed continuously, albeit with frequent brief interruptions. Although some children's individual patterns of play were quiet, silence was rare. Children used self-talk and regularly kept up a running description of the screen action or dialogued with peers. Positive affect dominated, with an overall emotional tone of excitement and fun characterizing many sessions. Children danced around, jumped, sang, and laughed. Celebratory-type actions often accompanied the completion of app goals. A child giggled and said "Look what I made!" after creating a virtual insect. The built-in app voice reward, "Good job" that occurred as a puzzle was completed often elicited raising hands, high fives, and jumping up and down. Children expressed their satisfaction with successful app completion, even when working alone.

> Transcript # 16- *Gary (5/M), is playing puzzles alone at table. Teacher stands nearby.*
> Gary: "I'm really good at this!"
> Teacher: "Yes, you have been practicing a long time."
> Gary: I'm so good at this"
> *Completes puzzle… Laughs…* Hee, Hee!

Children formed and reformed small groups, fluidly changing play partners. While three- or four-child groups were most frequently observed, at times as many as five or six children played cooperatively. Play varied within and among data collection sessions and included cooperative, parallel and onlooker play, and some collaborative play. (Parten 1932). Cooperative play, in which children work together to carry out some plan, was the most frequent type of play observed, particularly among a group of three or four children who played throughout the data collection period. The composition of this group varied somewhat over the study's course, with one child, Gary, a 5-year-old male who demonstrated advanced technology skills, as a consistent participant/leader. Gary enthusiastically participated in many observation sessions, using verbalizations and actions to direct peers, dictate app choices or solve technological problems. When playgroups formed, cooperative behaviors typically centered on choosing an app that all agreed upon, switching between apps, and assisting others with achieving the intrinsic goal of an app. The children frequently engaged in shared goal building with the Puzzle App (Fig. 1), and less so with the

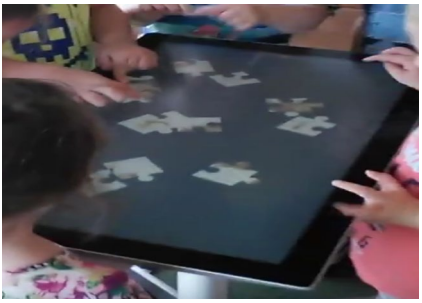

Fig. 1 Children engaged in puzzle app play

other apps. As is typical of social interactions in preschool years, more verbal or assertive children were able to control play.

Transcript #6: Teacher starts table, observes play initially, then leaves. A group of four children play with Puzzle App, which has alphabet/object four piece puzzles.
Gary (5/M) *initiates discussion about puzzle choice.*
Gary: "Okay should we do a Bear? No, Cat, Cat, Cat*." Loud voice, not yelling.*
App changes to Group Bubbles. (Unclear who changed it) Lucy starts to spin the bubble machine.
Lucy (4/F) : "I have a triangle bubble okay? Anything that has triangles they can come to mine."
Gary gives Lucy a bubble.
Lucy: "That's your bubble!"
Gary (to group): "If you need any circles come to me. Give me my circle bubbles back!"

App play frequently involved interactions focused on communicating ideas and information about how the app worked. Math Sentences (Fig. 2), an app made available near the study's end, engaged children working in groups as they discovered how the app worked.

Transcript #17: *Children are experimenting with new App to see if the frog would eat just one color insect, either purple or yellow. Children place one color on the log and the following exchange results:*
Jerry (3/M): "Why is he puking them out?" *to the teacher*
Teacher "He is spitting them out because they [numbers] are not the right equation."

Collaboration for problem solving was observed in apps that had frequent use. During Bubble play the exchange of ideas and information mainly focused on how to place all

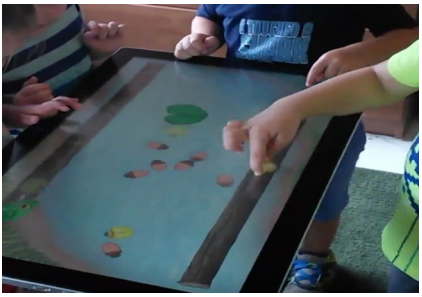

Fig. 2 Children engaged in math sentence play

items into a single bubble, including the bubble maker and Penelope. Early in the study while using the Puzzle App, the children spontaneously developed a system of assigning each child a piece, grouping pieces in "2 s" and then combining them to complete the larger puzzle. They continued using this system throughout the study.

Transcript #5. *Sam (5/M), Felipe(5/M), Jerry (3/M) and Gary (5/M) are working on Puzzle App.*
Sam:" I need a piece and Gary has two pieces."
Gary is holding his piece over on one side.
Jerry tries to fit his piece into Gary's
Sam and Gary work again to put their pieces together.
Sam: "We almost did it.. You guys just need to connect those pieces." *Talking to Felipe and Jerry*.
Sam: "Oh Felipe just did a piece."
Puzzle choice switched to Pizza.
Gary: "Let's try to make a pizza."
Teacher: "We need to decide as a group."
Sam: "I know, but I never cheat."
Boys mostly are ignoring the teacher except for Sam.
Jerry and Sam are working in the corner of table. Then Felipe and Gary put two pieces together. Jerry puts his piece in the puzzle.
Sam: "I let Jerry do that so I could put my piece on (Sam waits to be the last one to put in a piece.)
Sam and Gary then connect the two sides.
Puzzle App Voice: Good job! *Sam and Gary* smile at each other.
Jerry raises his hands and Jerry and Sam hug.

In Math Sentence play the children collaborated as they talked about what numbers to place on the log, and why the frog rejected certain numbers and accepted others.

Some children demonstrated parallel play, examples of which included: randomly moving objects; duplicating the play of the group, such as populating a bubble or creating an insect; aiding one another in finding an item; and exploring the table through small gestures. No parallel play occurred during puzzles. Children either participated in the puzzle's creation or left the table. However, even the children who most frequently engaged in cooperative and collaborative play used parallel play to meet their personal goals. During the last two sessions, Gary, who appeared to understand mathematics operations, persevered in his task to solve mathematical equations during the Math Sentences app, ignoring peers who were randomly scooping up insects and placing them on the logs.

Transcript #17- *Children are playing with the Math Sentences App. One frog on a log is available on each side of the table; insects fly through the screen. Gary (5/M) stands at the end of the table, peering at the frogs and logs while children randomly swipe insects and place on logs.*
One Frog asks for a sum of five
Gary: "I don't know how to make five." A*rms crossed over chest, thinking.*
Gary "I know, four and one" (places insects on log and frog eats)
Teacher "How did you know four and one made five?"
Gary "Because after four becomes five."

As children parallel played, they sometimes actively assisted each other in completing an individual goal. During one session of Insect Creator play (Fig. 3), children talked about

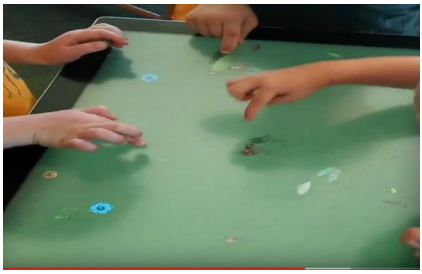

Fig. 3 Children engaged in insect creator play

the differences in insect body parts as they helped one another find specific body parts ("I need a head, I need a body") in order to complete the insect each child was completing. Boys moved around the table as they searched for body parts. Similar assistance occurred during Bubble Play as the children aided one another in finding items to place in the bubbles each individual child was populating. This type of help was qualitatively different from cooperative play. In cooperative play, the children worked to achieve a shared goal, not aid each other in completing an individual goal.

In reviewing the entire data collection period, solitary play (Parten 1932) was seldom observed. On only two or three momentary occasions during the approximately 300 min of data collection was a child observed working alone at the table. When that occurred, the child typically worked for only a few minutes, and then either abandoned the table for other choices or recruited others to join him/her.

Conflicts and play interruptions

Play was not always characterized by cooperation, positive affect and prosocial emotions. Sources of consistent social conflict included play interruptions by individual children, attempts to dominate or direct the play action and app choices,; and differing levels of social or technological skills. Documentation revealed outbursts of angry speech, arguments over apps and access to virtual characters or objects, and impulsive behaviors and physical intervention. Play interruptions most often occurred during Bubble Apps (Fig. 4) with the virtual character, *Penelope,* whose function was to pop the on-screen bubbles. Children quickly discovered the ease with which popping bubbles interrupted play. These interruptions could occur numerous times during a 20-min session, and continued throughout the data collection period particularly as a function of one or two children's play patterns. Jerry, a three-year-old male, consistently interrupted play, especially during the Bubble Apps. Rather than create bubbles, he used Penelope to break peers' bubbles as they were created. These actions persisted throughout the data collection period and often led to

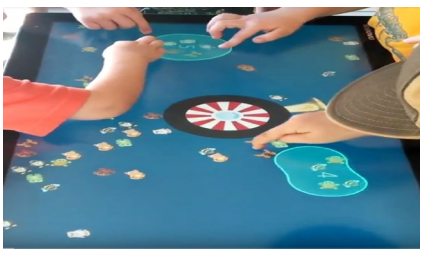

Fig. 4 Children engaged in bubble app play

instantaneous peer reactions such as yelling: "Stop popping bubbles! Stop popping them!" Sometimes physical actions followed verbal reactions, such as grabbing the hands of the child who was popping bubbles or pushing him/her away.

Transcript #2: *Three children, Sam (5/M), Jerry (3/M) and Kendell (5/M) are working together to place their items into one bubble. Jerry works on one end. His actions are limited to using Penelope to pop the bubbles as the group populates them.*
Sam: Jerry, you just wrecked our whole bubble."
Jerry: "Sorry guys, sorry"
Boys push Jerry's hands away.
Sam is spinning out bubbles from the machine.
"Can I have a bubble Sam?"
Kendall: "Give us all of them but not the porcupine. Don't pop it!" (to Jerry)
Sam holds Jerry's wrist. Repeats "Don't pop it Jerry!
Jerry puts finger on Penelope moves to bubble and he pops it.
Sam: "You always get the big bubbles with everything in them—that's not fair."
Kendall: "It just happens, it is fair."

Children also responded to peers who interrupted play by appealing to teachers or by exclusion. During Bubble App play, a child responded to a peer, Twyla (3/F) who was repeatedly popping bubbles: "Twyla has to go!" (to teacher). Twyla retreated to a nearby chair and hid her face, returning when teacher intervened.

Play interruptions occurred less frequently with other apps. Children *chopped* other's insects, or interrupted puzzle construction by repeatedly tapping the puzzle choice bar. Children sometimes hit the table, causing it to freeze, or made repeated spinning motions that prevented Apps from loading.

Social learning and collective agency

Children used a variety of ways to solve social problems. (See Table 2 for complete list of strategies). Children often quickly moved on from any conflict, and even when repeated interruptions occurred, children continued playing with the table with some success. There were some isolated instances of physical conflict, such as hitting or fighting. A child sometimes held the hands of another child or pushes him/her away. More typically, yelling, complaining and ignoring characterized social conflict.

Traditional methods of problem-solving, such as step-by-step problem-solving strategies common in early childhood environments (High Scope 2016) were generally ineffective and abandoned by children after initial steps. When encouraged by the teacher to "Use your words", a child asked "Can I have a bubble please…. Please can I have a bubble?" Peers ignored the request. This anecdote was typical of several problem-solving behaviors.

Transcript #5: *During Puzzle App, children are repeatedly changing the puzzle midplay. One child yells puzzle choices, which are ignored by the others. A teacher stopped play several times during conflicts:*
Teacher: "We need to decide as a group what puzzle to work."
Children ignore the teacher and continue to grab puzzle pieces.
Later, a teacher again reminds children to "Use their words" and models it for the children: "It makes me mad when…." *One child complies. No change in peer behavior was noted.*

Table 2 Child- initiated problem-solving strategies

Technology issues	Social interaction issues
Trial and error (systematic or intentional)	Inventing goals or play scenarios
Trial and error (random)	Discussion
Asking for teacher/adult assistance	Asking for teacher assistance
Asking peers and/or peer expert	Asking peers and/or peer expert assistance
Peer to peer- demonstration	Peer to peer-verbal instruction- directive
Peer to peer- verbal instruction	Peer to peer- yelling: complaining
Physical control of device	Physical actions- negative: holding others hands away, hitting
Taking hands off device	Physical actions- positive: high-fives, clapping, celebrating
Repeated actions, e.g. pushing icons	Sharing glee
Physical- random gestures	Negotiation and compromise
Waiting	Ostracism
"Thinking out loud" – describing one's actions to others	Inviting others to play
Selecting alternate apps	Cooperation in meeting app goals
Changing settings for current Apps	Assuming specific roles
Personification of table or apps	Social dominance
Planning with others	Planning with others-
Suggesting solutions	Suggesting solutions
Leaving table or refusing to play	Leaving table or refusing to play

There is some overlap between tech-related and social-related problem solving

Typically, by the time a traditional strategy was employed,such as a teacher asking "What is the problem here?" the action had moved on. Children solved problems by trial and error, by verbalizations or peer-instruction, by ignoring problems, and by starting another play scenario or app. Peer-to-peer mentoring was used throughout the study both for solving social conflict and technological issues. Children instructed others, using prior experience and knowledge or trial and error.

Social outcomes and technology competency

The multi-touch table was a new technology that brought technological challenges in the form of screens freezing, apps changing due to how the table was touched, and unexpected software updates. Similar to social problem-solving, the children developed a number of effective strategies to overcome these challenges (see Table 2). On one day (Transcript # 4), the table screen repeatedly froze. The teacher explained to the children that the screen froze when they laid their hands on the screen. The children quickly understood how to unfreeze the screen. After this day, when the screen froze one or more child would say "hands in the air" or "hands up" after which the screen unfroze and play continued. A second technology issue involved the location of the *Windows* symbol near the edge of the table. As children bent over the table to work, they often hit the symbol, causing the screen to leave the current app and move to the icon screen. The children learned to manipulate the screen back to the app. Children also turned to peers who they identified as proficient in technology.

Transcript #5. *Three children and one teacher are working on Puzzle App. Apps are continually switching. Teacher describes actions as she works without success.*
Teacher: "Let's get rid of this."
"Gary (5/M): "We need Kendall- Kendall always gets it."
Gary: "Kendall, we need your help."
Kendall (5/M)has been standing over to the side. Comes to table; touches app; Smiles.

A third technology issue occurred during software updates or low-battery messages. During one session, the update took 10 min, during which the children utilized several different strategies including pulling up chairs, leaving the table, lifting hands, and playing hand games until the update was finished. The teacher described the progress of the update and once the table was ready, children resumed play.

Discussion

Children's play in an interactive environment

The characteristics of children's play were simultaneously typical of early childhood settings and uniquely described within the context of the developmentally appropriate use of technology. Contrary to concerns about technology's promotion of social isolation or sedentary behaviors in young children, this study found children to be physically active and highly engaged with their peers in cooperative and collaborative play, similar to results found by (Couse et al. 2010). The study's interactive play sessions consisted almost entirely of children's sustained engagement with one another. Children reacted and responded to each other in the moment. Whether those interactions translate into general social skills cannot, however, be inferred from the data. The play moved at a constant pace, and required constant response. Distractions and interruptions were noted, but they did not stop the overall flow of play. CSCL devices' purpose is to promote collaborative, small-group learning. This study confirmed the utility of this device for promoting social play and group formation. While the nature of the play (extremely fast-paced, use of programmed, rather than child-created goals, etc.) may call for social and play-related skills different from that of other classroom materials, the play itself appeared to meet the traditional definition of generative play used in the early childhood field (Hirsch-Pasek et al. 2015). Simply put, children enjoyed using the device, and specifically enjoyed using it with peers. These types of shared experiences are prized by child development professionals as central to the function of play in children's lives as "transformative and empowering" (Nell, Drew & Bush, Nell et al. 2013, p. 57.)

Social learning and collective agency

The individual's perception of personal efficacy is the main factor in human agency (Bandura 1997). If a group of individuals develop a strong sense that they each can control the environment in which they interact with one another, the opportunity for collective agency development is in place. Because young children are mastering social learning, building collective agency is frequently complicated by impulsivity and conflict. The multi-touch table delivered a singular environment in which common goals were built into the

activities, providing an opportunity for individual and collective agency as well as social learning. Apps included built-in goals all children could see as they manipulated apps, producing shared goals. The touch-table technology in this study is specifically designed for group interaction, and group problem-solving with built-in, shared goals, such as building insects or working puzzles. Young children can and do explore and investigate digital technology by working together, sharing strategies and ideas (Moore (2017).

Parallel play aided in building individual agency using a social environment. For young children, parallel play is an important step toward cooperative play (Parten 1932). Parallel play was observed as children actively assisted one another in numerous ways. During Insect Creator play, children frequently found insect parts for each other, moving around the table as they searched. When populating bubbles during Math and Group Bubble play, children helped one another find specific objects. The objective of parallel play in both examples was individual—the help offered aided the individual child in achieving a goal (i.e. completing the insect or populating a bubble). Children successfully manipulated the apps for individual goals, building personal efficacy. The multi-touch table offered an environment in which children began with the building of personal efficacy, and ending in a collective agency. These results confirm anecdotal observations by teachers who found that use of tablet technology, rather than being socially isolating, was characterized by cooperation and collaboration. (Shifflet et al. 2012).

Collective agency was most frequently observed during puzzle play. When engaged in puzzle play, children worked together to select the puzzle, find puzzle pieces, and to fit the puzzle pieces together. As work on puzzles progressed, children moved around the table, talked, and exchanged ideas on how to complete the puzzle. Significantly, a lone child was rarely observed playing with the Puzzle app. Traditional puzzles are typically individual activities, but on the multi-touch table, the Puzzles app was a social and collaborative activity. In Math and Group Bubble play, collective agency emerged as children engaged in the goal of populating a single, large bubble. The children embraced the concept of one large group bubble to the extent that they placed Penelope and the bubble machine together with the pictures. When finished, the children exclaimed in excitement and celebrated.

As the above examples illustrate, group problem solving was important to social learning as collective agency was built. There were examples in which group problem solving was missing, as when Gary solved the addition problem $4+1=5$. These types of individual examples were rare. In the case of Gary, the reason for the solitary problem solving may have been his advanced knowledge of mathematical concepts. Problem solving occurred as children resolved their conflicts, but the continuous nature of the apps influenced the process. The fast pace of the apps did not provide children time to stop and carefully develop a traditional resolution to conflict (High Scope 2016). Instead, children resolved conflict collectively quickly by ignoring the conflict, trial and error, verbalization, appealing to the teacher, and peer mentoring (Table 2). The consistency in all conflict resolution was the lack of time for careful, collective decision-making.

Collaborative social outcomes and technology competence

The results from this study supports the suggestion by Rick et al. (2009) that multi-touch tables do not present the same single-user constraints found in tablets. Young children can interact when manipulating a tablet (Beschorner et al. 2013,) but the ability for multiple children to gather around the screen and simultaneously share in the activity is limited. The concern that screen time results in inactivity and passive participation (NAEYC 2012)

was not supported. The apps had built in goals that all of the children could see. The table itself provided a shareable interface for small group learning. Small groups are a critical part of DAP (Copple et al. 2009) in an early childhood classroom, and the multi-touch table presented an environment that encouraged small group collaboration. The Puzzle App provides an excellent example, as children problem-solved the puzzles and celebrated together by dancing and exclaiming. In the example of the Puzzle App, the multi-touch table provided the children a group collaborative experience that traditional puzzles do not. The Engage-2 table provided a CSCL environment for young children that is qualitatively different from a laptop or traditional tablet (Hwang et al. 2015), through its multi-user orientation and participation, as well as apps with built-in group goals. In addition, the fluid nature of digitized games permitted speedy and responsive attempts, re-boots and new starts, unlike other real-world tools such as traditional board games, group art work or puzzles. (Moore 2017).

ISTE-S (2016) stresses empowered learning and perseverance as important components to student use of technology. Young children are building the technology skills that provide the foundation for empowered learning that includes understanding technology operations. Numerous examples from children's play occurred as they swapped parts (Insect Creator), collaborated towards a goal (Math and Group Bubbles), and selected and collaborated to complete a task (Puzzles), indicating "the ability to choose, use, and troubleshoot current technology" (ISTE-S 2016). Children exhibited high levels of patience with technology operations through perseverance in resolving technology problems. A variety of strategies were used by the children when there was a software update, frozen screen, or unexpected change in the screen. If the technology issue recurred, children quickly learned to troubleshoot based on prior experience, utilizing such tactics as holding their hands up to "unfreeze" the screen, or not avoid touching the *Windows* sign. When a software update came up, children waited patiently as they brought chairs up to the table, played finger games, or had a general discussion. If something unexpected arose, children referred to strategies their parents used or in one instance, called a peer over to help who was perceived as able to solve the problem. The ability to adapt quickly with patience and perseverance are characteristics of digital natives demonstrated by the children (Bittman et al. 2011).

Limitations and future research

The descriptive nature of the study revealed several potential areas for further exploration, particularly with regard to the role of the teacher, gender and age differences during child play, and the goal of improving children's overall social and emotional skills. No real evidence of growth or change in the children's social skills were noted from start to finish. The children who dominated play at the beginning were still doing that at the end. The children who interrupted the play did so whenever they used the table. Children, however, devised ways to continue play with peers. Comparing the frequency of peer mentoring in a CSCL environment as opposed to non-tech small group play would be an interesting investigation into whether technology has a unique role to play in this prized learning skill. The focus of this article rested on child-to-child interactions, with few references to teacher strategies or teacher–child interactions. The impact of technology on these crucial areas, particularly in relation to recommended teacher practices is an essential topic, and the omission of teacher recommendations in this article is intentional. This topic will be more fully explored in a

current follow-up study and additional articles. Exploring the reasons why children did not participate, or participated rarely is an additional avenue for research.

A strength of qualitative research is the emergence of unexpected results. The abilities of one or two children to control the play, perhaps due to their technological expertise or conversely, by their abilities to interrupt the play of others was striking. App designs when combined with a particular configuration of children playing at any given time, was an interesting finding. This technological/social interaction created unique problem-solving/interaction patterns, and will be a rich topic for future research.

Several limitations are present in this study. Although this is an exploratory, qualitative study, the convenience sample size of 18 children in a single classroom is small. The children self-selected to play at the Engage-2 table, and app choices were intentionally restricted. The Engage-2 multi-touch table created the opportunity for a computer supported collaborative learning environment as children engaged in high levels of social play and group formation. Children exhibited joy and enthusiasm as they manipulated the apps while interacting with their peers. Children clearly worked from parallel to cooperative play and some collaborative play, as behaviors that began as individual agency turned to collective agency within the CSCL environment. The young children in this study engaged in empowered learning and perseverance not only as they manipulated Apps, but as they learned how to problem-solve through technology issues and social problems. The computer supported collaborative skills evidenced in this study may lay the foundation for virtual collaborations that arise in later schooling and CSCL environments.

Compliance with ethical standards

Conflict of interest Dr. Donna Karno and Dr. Beth Hatcher declares that they have no conflict of interest. Kaplan Early Learning Company provided the multi-touch table for the research, but did not become involved beyond furnishing the table.

References

Armstrong, A., & Casement, C. (2000). *The child and the machine: How computers put our children at risk*. Beltsville: Robins Lane Press.

Bandura, T. (1977). *Social learning theory*. Englewood Hills: Prentice-Hall.

Bandura, A. (1997). *Self-Efficacy: The exercise of control*. NY: W.H. Freeman and Company.

Bause, I. M., Brich, I. R., Wesslein, A., & Hesse, F. W. (2018). Using technological functions on a multi-touch table and their affordances to counteract biases and foster collaborative problem solving. *International Journal of Computer-Supported Collaborative Learning, 13*(1), 7–33.

Beschorner, B., & Hutchison, A. (2013). iPads as a literacy teaching tool in early childhood. *International Journal of Education in Mathematics, Science and Technology, 1*(1), 16–24.

Birch, L., Parker, L., & Burns, A. (Eds.). (2010). *Early childhood obesity prevention policies*. Washington DC: National Academies Press.

Bittman, M., Rutherford, L., Brown, J., & Unsworth, L. (2011). Digital natives? New and old media and children's outcomes. *Australian Journal of Education (ACER Press), 55*(2), 161–175.

Castle, K. (2012). *Early childhood teacher research: From questions to results*. NY: Routledge.

Chen, J., Wang, M., Kirschner, P. A., & Tsai, C.-C. (2018). The role of collaboration, computer use, learning environments, and supporting strategies in CSCL: A meta-analysis. *Review of Educational Research, 88*(6), 799–843. https://doi.org/10.3102/0034654318791584.

Cicconi, M. (2014). Vygotsky meets technology: A reinvention of collaboration in the early childhood mathematics classroom. *Early Childhood Education Journal, 42,* 57–65. https://doi.org/10.1007/s10643-013-0582-9.

Copple, C., & Bredekamp, S. (Eds.). (2009). *Developmentally appropriate practice* (3rd ed.). Washington, DC: NAEYC.
Couse, L. J., & Chen, D. W. (2010). A tablet computer for young children? Exploring its viability for early childhood education. *Journal of Research on Technology in Education, 43*(1), 75–98.
Creswell, J. (2012). *Qualitative inquiry and research design: Choosing among five traditions* (3rd ed.). Thousand Oaks: Sage.
Fred Rogers Center for Early Learning and Children's Media at Saint Vincent College. (2012). *A framework for quality in digital media for children: Considerations for parents, educators, and media creators*. Latrobe: Fred Rogers Center.
Garvis, S. (2016). Digital technology and young children's narratives. In S. Garvis & N. Lemon (Eds.), *Understanding Digital Technologies and Young Children*. NY: Routledge.
Geist, E. (2014). Using tablet computers with toddlers and young preschoolers. *Young Children, 69*(1), 58–63.
Gress, C. L. Z., Fior, M., Hadwin, A. F., & Winne, P. H. (2010). Measurements and assessment in computer-supported collaborative learning. *Computers in Human Behavior, 26*(5), 806–814. https://doi.org/10.1016/j.chb.2007.05.012.
Gu, X., Wang, H., & Mason, J. (2017). Are they thinking differently: A cross-cultural study on the relationship of thinking styles and emerging roles in computer-supported collaborative learning. *Journal of Educational Technology & Society, 20*(1), 13–24.
Hatcher, B., & Squibb, F. (2011). Going outside in winter: A qualitative study of preschool dressing routines. *Early Childhood Education Journal, 38*(5), 339–347.
High Scope. (2016). *Conflict resolution steps*. Ypsilanti: High Scope Foundation.
Hirsch-Pasek, K., & Golinkoff, M. (2015). Introduction. In H. Bohart, K. Charner, & D. Koralek (Eds.), *Exploring play* (p. 1). Washington, DC: NAEYC.
Ho, J., & Funk, S. (2018). Promoting young children's social and emotional health. *Young Children, 73*(1), 73–77.
Hwang, W.-Y., Shadiev, R., Tseng, C.-W., & Huang, Y.-M. (2015). Exploring effects of multi-touch tabletop on collaborative fraction learning and the relationship of learning behavior and interaction with learning achievement. *Journal of Educational Technology & Society, 18*(4), 459–473.
International Society for Technology in Education. (2016). *ISTE Standards – Students*. Retrieved from http://www.iste.org/standards/standards/standards-for-students
Jackson, A. T., Brummel, B. J., Pollet, C. L., & Greer, D. D. (2013). An evaluation of interactive tabletops in elementary mathematics education. *Educational Technology Research and Development, 61*(2), 311–332.
Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Newbury Park: Sage.
Mawson, J. B. (2013). Emergent technological literacy: What do children bring to school? *International Journal of Technology and Design Education, 23*(2), 443–453.
McEwen, R. N., & Dubé, A. K. (2015). Engaging or distracting: Children's tablet computer use in education. *Journal of Educational Technology & Society, 18*(4), 9–23.
McPake, J., Plowman, L., & Stephen, C. (2013). Preschool children creating and communicating with digital technologies in the home. *British Journal of Educational Technology, 44*(3), 421–431.
Mercier, E. M., Higgins, S. E., & Joyce-Gibbons, A. (2016). The effects of room design on computer-supported collaborative learning in a multi-touch classroom. *Interactive Learning Environments, 24*(3), 504–522.
Moore, H. C. (2017). Look what I made! Open-ended apps that spark creativity. *Young Children, 72*(5), 21–27.
Moore, H. C., & Adair, J. K. (2015). I'm just playing iPad!: Comparing prekindergarteners' and preservice teachers' social interactions while using tables for learning. *Journal of Early Childhood Teacher Education, 36*(4), 362–378.
National Association for the Education of Young Children & Fred Rogers Center for Early Learning and Children's Media at Saint Vincent College. (2012). *Technology and interactive media as tools in early childhood programs serving children from birth through age 8.* Retrieved from: http://www.naeyc.org/content/technology-and-young-children
Nell, M., Drew, W., & Bush, D. (2013). *From play to practice: Connecting teachers' play to children's learning*. Washington, DC: NAEYC.
O'Mara, J., & Laidlaw, L. (2011). Living in the iworld. Two literacy researchers reflect on the changing texts and literacy practices of childhood. *English Teaching-Practice and Critique, 10*(4), 149–159.
Office of Administration for Children and Families: Head Start Learning Framework (2015). Retrieved from: http://eclkc.ohs.acf.hhs.gov/hslc/hs/sr/approach/elof

Paciga, K. A. & Donohue, C. (2017). *Technology and interactive media for young children. Latrobe PA: Fred Rogers Center for Early Learning and Children's Media at Saint Vincent College.*
Parten, M. (1932). Social participation among preschool children. *Journal of Abnormal and Social Psychology, 27,* 243–269.
Plowman, L., & McPake, J. (2012). Seven myths about young children and technology. *Journal of Childhood Education, 89*(1), 27–33.
Rick, J., Rogers, Y., Haig, C., & Yuill, N. (2009). Learning by doing with shareable interfaces. *Children, Youth and Environments, 19*(1), 320–341.
Riley, D., San Juan, R., Klinkner, J., & Ramminger, A. (2008). *Social and emotional development: Connecting science and practice in early childhood settings*. Washington, DC: Redleaf Press.
Robson, S. (2016). Self-regulation, metacognition, and child- and adult- initiated activity: Does it matter who initiates the task? *Early Child Development and Care, 186*(5), 764–784.
Romeo, G., Edwards, S., McNamara, S., Walker, I., & Ziguras, C. (2003). Touching the screen: Issues related to the use of touchscreen technology in early childhood education. *British Journal of Educational Technology, 34*(3), 329–339.
Rosen, D., & Jaruszewicz, C. (2009). Developmentally appropriate technology use and early childhood teacher education. *Journal of Early Childhood Teacher Education, 30*(2), 162–171.
Shifflet, R., Toledo, C., & Mattoon, C. (2012). Touch tablet surprises: A preschool Teacher's story. *Young Children, 67*(3), 36–41.
Travers, J. C., & More, C. M. (2013). TECH IT. In H. Parette & C. Blum (Eds.), *Instructional technology in early childhood*. Baltimore: Brookes Publishing.
Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge: Harvard University Press.
White House Task Force on Childhood Obesity. (2010). *Solving the Problem of Childhood Obesity within a Generation*. Washington DC: Office of the President of the United States.
Willis, C., & Schiller, P. (2011). Preschoolers' social skills steer life success. *Young Children, 66*(1), 42–49.
Wolfe, S., & Flewitt, R. (2013). New technologies, new multimodal literacy practices and young children's metacognitive development. *Cambridge Journal of Education, 40*(4), 387–399. https://doi.org/10.1080/0305764x2010.526589.

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