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A Comparison of Expert vs. Novice Delivery of STEAM-based Instruction on the Academic Achievement of Kindergarten Students

Sandy White Watson[*], Brenda G. Weiser[**] Jeremy Dean Unruh[***]

Abstract

In an earlier research project (2014-2015) a university in the southcentral US in collaboration with a local Independent School District (ISD) configured a Curriculum Design Team who designed, developed, and reviewed a STEAM (Science, Technology, Engineering, Mathematics with integrated arts) based multimodal curriculum. The curriculum was developed on the foundation of social constructivist pedagogical strategies and science and engineering processes and sought to explore the curriculum impact on underserved kindergarten students' school academic achievement and readiness, inclusive of levels of literacy learning, cognitive development, academic achievement, and consequently, social/behavioral performance. The current comparative, case study examined the effects of the aforementioned STEAM-based integrated hands-on science activities, and on participating underserved kindergarten students' academic achievement in science content from the context of teacher expertise (expert vs. novice). Two science lessons with the same content were utilized as the reference point for comparison to reveal the science academic achievement of students when delivered by an expert teacher versus a novice teacher. Additionally, the researchers examined how hands-on science activities affected the participating expert and novice teachers' pedagogical beliefs and practices regarding the inclusion of science in the kindergarten classroom.

Keywords: Expert, Kindergarten, Novice, STEAM, Teacher

[*] University of Louisiana Monroe
[**] University of Houston
[***] San Jacinto Community College

Introduction

STEAM education in the early childhood setting and the impact of STEAM practices and beliefs on student achievement is one of the foci of this study. The differences in science learning outcomes of kindergarten students whose teacher was considered an expert versus those of students whose teacher was a novice via a researcher developed science assessment instrument correlated to the Texas Essential Knowledge and Skills (TEKS) were examined. The researchers further explored the pedagogical beliefs and practices of the teacher participants prior to and after they received the STEAM training via a Teacher Beliefs and Practices Survey. And finally, researchers interviewed the teacher participants concerning their perceptions of the STEAM curricula via focus group interviews twice during the academic year, once at the inception of the study, and once at the culmination of the study. From these data, case studies were developed of both expert and novice teachers for comparison purposes.

Background and Research Goals

A previous research pilot study was initiated as a venture of a newly established collaborative partnership between the participating school district and a university in southeastern Texas. This study took place during the 2014-2015 school years and was comprised of the collaborative development of a STEAM based multimodal curriculum. The curriculum was developed on the foundations of social constructivist pedagogical strategies and science and engineering processes and sought to explore its curriculum impact on underserved kindergarten students' academic achievement and readiness, inclusive of levels of literacy learning, cognitive development, academic achievement, and consequently, social/behavioral performance. Formative evaluations of the curriculum, observations, and focus group data have indicated a lack of science content in the STEAM curriculum at this particular school.

For the current study, three research goals were identified. (RQ1) What are the differences in early childhood student achievement among students taught with STEAM-based hands-on science activities by an expert teacher versus a novice teacher? (RQ2) How does utilizing STEAM-based hands-on science activities affect teachers' pedagogical beliefs and practices? (RQ3) Does Professional Development supporting integration of STEAM-based hands-on science activities impact teachers' perceived ability to implement science activities in the classroom?

In the current study, the STEAM curriculum previously put in place during the pilot study was still operating. All kindergarten teachers provided instruction pertaining to a question of the week related to STEAM. Students received STEAM content knowledge related to the question during their regular class time as they moved among

STEAM stations. Then once a week they attended Science Lab along with their teachers. During Science Lab, a specialized science teacher facilitated investigations related to the science question. Finally, students went to Engineering Lab, where yet another specialized teacher guided them through applications related to the question. Students followed the engineering design (ask, imagine, plan, create, improve, present) in this last setting as they applied what they learned.

Review of Related Literature

STEAM in Early Childhood Education

It has only been recently that early childhood/elementary education has been inclusive of STEM concepts (Parette, Quasenberry & Blum, 2010; Tippett & Milford, 2016; Trundle, 2010). However, the National Science Teachers' Association position statement on early childhood science education strongly "supports the learning of science among young children that will create a seamless transition for learning in the elementary school" and encourages the development and inclusion of activities that support science engagement on a daily basis (2014, p. 1). Exposure to developmentally appropriate STEM activities provides opportunities for children to actively engage with real-life hands-on materials and to experiment, investigate, and fully engage their five senses (Moonaw & Davis, 2010; Simoncini & Lasen, 2018). While some in education may question the wisdom of integrating STEM into kindergarten settings, young children exhibit a natural curiosity for learning (Callanan & Oakes, 1992; Duschl, Schweingruber, & Shouse, 2007). Eggers (2007) noted that "in early childhood it is equally important that science activities be hands-on, child-driven, authentic, and active" (p.1).

Prior research indicates young children construct their own knowledge and understanding of the world by acting on, and interacting with, the environment, their teachers, family members, peers, older children, materials, books and forms of technology (Dewey, 1916; Fosnot, 1996; Piaget & Cook, 1952; Vygotsky, 1978).

STEAM (STEM with integrated Arts) is a recent addition to early childhood education and is often conceptualized as an extension to the existing curriculum. Delaney (2014) posited that the "art" component refers to the liberal arts, as opposed to the singular "art," which refers to musical, performing, visual, etc. art. STEM advocates argue that arts are already present in STEM curricula via creativity and design (Williams, 2013), especially during presentations. An example might include student-produced videos or computer graphics for project or problem-based learning challenges. While STEAM is still in its initial stages of evaluation (Kang, Park, Kim, & Ki, 2012), early findings have shown that "STEAM-based curricula increase motivation, engagement, and effective disciplinary learning in STEM areas" (Quigley, Herro, & Jamil, 2017).

Moreover, Masata (2014) found that students participating in STEAM curricula are more diverse and demonstrate greater interest in pursuing careers in mathematics and science. Including arts in STEM makes the curriculum more appealing to a wider pupil audience and can help students visualize real-world connections (Kang, et al., 2012). Through integrated STEAM lessons, students have an opportunity to gain awareness that "even though science, technology, engineering and math are different, they are intricately related in the problem-solving process" (Lott, Wallin, Rogharr, & Price, 2013, p. 69).

The National Science Board (NSB, 2010) stresses the importance of early exposure to STEM opportunities and inquiry-based learning so that young children become interested in STEM careers. In addition, it has been recommended that development of science talent begin in the earliest grades so that young students would be more likely to want to pursue science studies as they proceed through their schooling (Brandwein, 1995; MacDonald, Huser, Sikder, & Danala, 2019). Keeley (2009) and Goldstein (2005) argued that when science is not included in the early childhood curricula, conceptual comprehension of and achievement in science is negatively impacted. In addition, if a young child's natural curiosity in and enthusiasm for science is not fostered, it may continually diminish (Pratt, 2007). Eventually, students who display an early interest in STEM but do not receive encouragement to further develop that interest, may lose that interest and pursue another discipline or may never select an advanced science course for further study (Cotabish, et al., 2013).

In order for STEAM curricula to be successfully implemented in elementary school settings, the teachers in these schools must be willing to lead STEAM initiatives and must possess the necessary STEAM content knowledge so that they may competently and confidently deliver STEAM content instruction. Therefore, according to Cotabish et al., (2013) it is critical that elementary teachers be provided research-based STEAM professional development.

Cotabish, et al. (2013) and Brandwein (1995) stated that one of the greatest obstacles to cultivating science talent is ineffectually prepared teachers. Whether or not a teacher has a thorough understanding of the nature of science processes and a command of the language of science impacts the cultivation of STEM learners in his or her classroom (Michaels, Shouse, & Schweingruber, 2008). Not only must elementary teachers have an understanding of how science works they must also possess the ability to design science instruction for their students and be able to make that science instruction authentic to their students' lives (Michaels, Shouse, & Schweingruber, 2008). Johnson, Kahle, and Fargo (2006) discovered that student achievement in science increases when teachers utilize inquiry-based learning and engage students with purposeful science learning. Robinson, Dailey, Hughes & Cotabish (2014) determined that elementary students of teachers who employed inquiry-based instruction supported by relevant professional development in STEAM showed statistically significant gains in their knowledge of science process skills, science concepts, and science content knowledge when compared to students who were not exposed to such teachers. In fact, elementary teachers can be door openers or gatekeepers toward fostering STEM achievement in their students, and thus can also positively or negatively affect choices their students may make regarding the pursuit of STEM careers (Cotabish et al., 2013).

Expert and Novice Teacher Differences

The research literature is replete with educational theories centered around recommended pedagogical strategies (Verloop, Van Driel, & Meijer, 2001) but is deficient of current practical studies pertaining to differences in expert versus novice teachers' pedagogical beliefs and practices (Wolff, van den Bogert, Jarodska, & Boshuizen, 2015). Most studies to date have focused on the pedagogical knowledge of either expert (Johnston & Goettsch, 2000) or novice teachers (Tsui, 2003, 2005) but few place expert and novice together in the same study. Comparative case studies on expert versus novice teachers in the early childhood setting are thus lacking in the literature. Examining both novice and expert teacher together in the same study, allows the researcher to scrutinize very specific areas and better determine how the teachers are alike or different.

Earlier understandings of teacher expertise centered on the notion that cognitive processes occurred only in the minds of individuals and were independent of context (e.g., Chase & Simon, 1973 & Glaser & Chi, 1988). Later researchers challenged that belief, citing ethnographic case studies of the lives of teachers which indicated that their pedagogical knowledge and beliefs were intertwined with the context of their work and their personal stories (Sing, 2010). Still later investigators found that teacher expertise is social psychological, meaning that expertise does not reside alone with an individual (Clancey, 1997), but is also found in the "interaction between the individual and the context in which he or she operates" (Tsui, 2005, p. 422).

The research literature is divided regarding the number of years of practice a teacher must have to be considered experienced. For example, Richards, Li, & Tang (1998) and others (Tsui, 2003, 2005) define experienced teachers as generally having four or more years of practice and novice teachers as those who have taught less than three years. Kelchtermans (1993) stated that it generally takes about ten years for an inexperienced teacher to become experienced. In addition, expertise is often intertwined with years of experience. However, experience alone is an insufficient condition of expertise as Bereiter and Scardamalia (1993) found in their study of experienced and novice writers. Years of practice does not necessarily lead to exemplary writers, but may result in not-so-good, self-assured writers (Bereiter & Scardamlia, 1993). Likewise, many experienced teachers continue to be non-exemplary (Tsui, 2003). However, experience is a compulsory element of expertise (Rich & Almozlino, 1999).

According to Tsui (2009), expertise is viewed as “a state of superior performance achieved after a number of years of experience and practice and is characterized by efficiency, automaticity, effortlessness, and fluidity” (p. 422). Bereiter and Scardamalia (1993) posited that while experts tend to solve the kinds of problems that will increase their expertise, novices will more likely seek out problems they perceive to be easier to solve. Furthermore, Meyer (2004) described novice teachers as having “restricted and poorly organized knowledge bases” (p. 972). Meyer went on to say that novice teachers “perceive events and process the meaning of those events narrowly, which limits their problem-solving” (2004, p. 972). Hattie (2003) synthesized data from more than 500,000 teaching studies to determine the characteristics of exemplary educators and identified the following dimensions of teacher expertise: (1) the ability to recognize critical depictions of their subject areas, (2) the ability to utilize classroom interactions to facilitate learning, (3) competency in guiding instruction and providing feedback, and (4) the capacity to positively impact student outcomes.

Additionally, because experts have become proficient in certain tasks, those tasks become routine, resulting in a net gain of time that the experts then utilize to confront more difficult problems. In contrast, novice teachers who become task-proficient are more likely to use their net gain of time pursuing fewer tasks or other simpler tasks. Thus, it is when people “work at the edge of their competence” (Bereiter & Scardamalia, 1993, p.4) to attempt more complex problems to broaden their proficiency that they cultivate their expertise. In addition, novice teachers were found to focus more on the selection and flow of learning activities (Akyel, 1997) rather than the curricula as a whole. Similarly lacking in the repertoire of novice teachers is the ability to “integrate a range of knowledge linked to the act of teaching” (Wolf, van den Bogert, Jarodzka, & Boshuizen, 2015, p. 70). Expert teachers also tend to possess the ability to continuously and consciously contemplate and reflect upon their teaching practice (Wolff, Jarodzka, van den Bogert, & Boshuizen, 2016). Tsui’s (2003) case study of four ESL teachers with differing expertise and experience revealed the qualitative differences (for example, classroom management, cognitive processing) between novice and expert teachers. Finally, teacher experts are perceived to be not only in possession of the best pedagogical skills and knowledge (Happo, Maatta & Uusiautti, 2012), but are able to apply those skills in their practice (Selinger & Crease, 2006; Wood & Bennet, 2000).

Several researchers indicate that the improvement/growth of new teachers is highly dependent upon their beliefs of foundational educational concepts and their ability to put those beliefs into practice (Barmald, Hardman, & Leat, 1995; Rich & Almozlino, 1999; Taylor & Sobel, 2001). In addition, according to Haney and McArther (2002), when preservice teachers’ core educational beliefs were lacking, they experienced frustration and failure, causing them to abandon the perceived problematic pedagogical strategies.

The majority of studies related to teacher pedagogical knowledge and beliefs have been centered on either experienced/expert teachers (Binnie-Smith, 1996; Breen, 1991; Gatbonton, 1999; Johnson & Goettsch, 2000; Tsui, 2009) novice teachers (Almarza, 1996; Johnson, 1992), or comparative studies, (Peterson & Comeaux, 1987) but studies of early childhood teacher expertise and beliefs are rare. Moreover, comparative studies of early childhood novice and expert teachers' practices and beliefs pertaining to STEAM education are missing from the literature.

Methods

This study employed the Extended-Term Mixed-Method Evaluation (ETMM) design (Chatterji, 2004) that included a long-term timeline, an evaluation guided by the project's purposes, a deliberate incorporation of formative and summative data collection/analysis, sharply focused performance measures, and quantitative and qualitative evidence. To establish construct validity, multiple sources of evidence were utilized, and a chain of evidence was established (via references to a case study database) (Dinour, Kwan, & Freudenberg, 2017). The case study database was also developed for reliability purposes as the database (containing the transcribed semi-structured interviews) served as a formal collection of evidence available for review by interested stakeholders at a later time. The comparative cast study methodology was selected in part because the cases scrutinized within the study are purposely chosen for their particular characteristics (novice or expert) and because comparative studies "provide the strongest evidence about the effects of education interventions" (Porter, 1997, p. 523). To minimize measurement for error in the utilization of the comparative case study methodology and to increase internal validity, a predicted pattern or theory is described prior to data collection (Dinour, Kwan, & Freudenberg, 2017). The predicted findings for this study are provided in the 'predicted findings' section. Yin (1994) defines a case study as "an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (p. 13). Merriam (1988) further clarifies a qualitative case study as "an intensive, holistic description and analysis of a single instance," phenomenon, or social unit" (p. 21).

In addition, science content pre- and post-assessments were administered to each of the two participating student classes (novice and expert). The pre-assessment was given at the inception of the project while the post-assessment was administered at the end of the project. Focus group interviews with the two participating teachers were conducted two times, once at the beginning of the project, and once at the culmination of the project. Conversations were recorded for later analysis. Finally, the two participating teachers each completed the teacher beliefs and practices survey.

Participants

A purposeful sample of two kindergarten teachers (research participants) was selected to take part in this study due to their levels of experience in teaching (novice and expert) and a convenience sample of their 40 students was selected for participation. The study took place in a large, suburban school district located in the southeastern US that had a partnership with the university at which the researchers were employed. Years of experience, educational degrees, positions of educational leadership held, and teaching awards earned were criteria of expertise. Both research participants were White females, one with a bachelor's degree in early childhood education and two years of teaching experience (novice teacher), and one with a master's degree in early childhood education and eighteen years of experience (expert teacher). In addition, the expert teacher participant was the kindergarten team leader, had received the school's teacher of the year award, and was a runner-up to the district's teacher of the year award. Both the expert and novice teacher had twenty students in their respective classes. The expert teacher's students were 70% Hispanic while the novice teacher's students were 80% Hispanic and both student groups presented 100% free and reduced lunch. The student participants were selected because they were students in the expert and novice teachers' classrooms, thus their selection for this study was out of convenience.

Teachers' Preparation for Teaching from the STEAM Curriculum

During the Fall of 2015 immediately preceding the implementation of the research study, both teacher participants received three hours of a Professional Learning Experience in the Growing Up Wild curriculum (Council for Environmental Education, 2016). This training included how to develop stations focusing on specific STEAM learning themes. In the spring of 2016, each teacher participant received an additional three hours of a Professional Learning Experience in Project Learning Tree's early childhood curriculum and their Green School's Curriculum (American Forest Foundation, 2013). In this training, the teachers explored energy, environmental quality, waste, recycling, and water.

Both novice and expert kindergarten teachers taught their students from the STEAM curriculum, integrating mathematics into their science instruction and provided hands-on science activities for their students. They also included manipulative-based math activities germane to the science content. In addition, both student groups were exposed to teacher-created STEAM stations.

Instrumentation

Prior to and following the administration of the STEAM curricula, student participants were administered a researcher-developed science content assessment instrument based on the TEKS for kindergarten. The instrument was used for both pre- and post- test assessment to evaluate participating kindergarten student learning outcomes in science content. The Teacher Beliefs and Practices Survey was also administered to both participating teachers. A post-only survey was utilized to determine the perceptions of each teacher related to their willingness (comfort levels) in using the new STEAM based hands-on science activities. The Teacher Beliefs and Practices Survey is a 72-item survey utilizing a Likert scale to measure pedagogical beliefs (1 = not at all important; 2 = not very important; 3 = fairly important; 4 = very important; 5 = extremely important) and instructional classroom strategies (1 = almost never; 2 = rarely; 3 = sometimes; 4 = regularly; and 5 = very often). This survey was a measurement designed specifically for teachers of children aged 3-5 and was devised to reflect the concepts of DAP (developmentally appropriate practices) as outlined in the NAEYC (1997) guidelines. Kim (2005) utilized Cronbach's alpha to establish reliability of the Beliefs Scale (.858). The Teacher Beliefs and Practices Survey was administered as a pre-test to both teacher research participants prior to the first observation of the teachers teaching from the STEAM curricula.

Data collection procedures

Prior to data collection, IRB approval was granted. Professional development was conducted in the Fall of 2015 and Spring of 2016 and implementation of an inquiry-based STEAM curriculum occurred simultaneously.

Students in the classes of the participating teachers were administered the researcher-developed science content assessment instrument as a pre-test prior to being exposed to the STEAM curricula. Next, the STEAM based hands-on activities were implemented in the two kindergarten classrooms. The student participant sample consisted of 20 expert teacher group participants and a similar group of 20 novice teacher group participants. Immediately following exposure to the STEAM based hands-on activities, student participants were again administered the researcher-developed science content assessment (post-test) based on the TEKS for kindergarten.

Throughout the academic year, the participating teachers (novice and expert) were observed as they were teaching the STEAM curricula to their kindergarten classes for a total of four observations each. Notes were taken by observers (trained university faculty) as the observations took place. The notes were immediately presented to the researchers following each observation.

Twice throughout the academic year (once prior to STEAM training and once at the end of the project), the novice and expert teachers were brought together for a focus group interview conducted by a university faculty member who audio taped the proceedings. The exact time and locations of the interviews were negotiated between the participants and the university faculty member. Teacher focus group participants signed consent forms and were provided pseudonyms to protect their privacy. The lengths of the interviews were approximately one to two hours. The semi-structured interview format was open-ended, although some of the specific questions were planned in advance. As the interviews progressed, new questions were formulated based on the personalities of the teacher participants, the experiences they offered, and time constraints. All audiotapes were transcribed for analysis.

Data Analysis

The student scores from the two participating classes on the science content assessment as well as the results of the Teacher Beliefs and Practices Survey were analyzed utilizing paired t-tests, frequencies, and percentages. Utilizing the pre-scores from both teacher's students, an independent t-test was conducted to establish baseline equivalence ($p < .05$).

The transcripts were read and re-read for emergent themes or the emergence of categories of meaning (Glaser & Strauss, 1967). Marshall and Rossman (2010) stated that in this phase, "the researcher does not search for the exhaustive and mutually exclusive categories of the statistician but, instead, identifies the salient, grounding categories of meaning help by participants in the setting" (p. 154). A color-coded system was applied to the data to identify emerging themes, categories and patterns and the data were ultimately reduced per Cohen, Kahn & Steeves (2000).

Focus Group Interviews

There were four primary themes that emerged from the focus group interviews. These included: (1) General beliefs related to STEAM curriculum; (2) Self-efficacy related to STEAM curriculum; (3) Impact of STEAM on students, and (4) Previous experiences with STEM/STEAM.

Beliefs related to STEAM curriculum theme

Both the novice and expert teachers indicated that their students seemed to enjoy the STEAM curriculum because it was student-centered. The novice teacher stated that both she and her students appreciated the STEAM curriculum because it employed hands-on activities and mathematics connections, while the expert teacher indicated that the content in the STEAM curriculum seemed more relevant to students and that its connection to literacy also made it appealing.

When asked if they believed professional development supporting the integration of STEAM-based hands-on science activities impacted their ability to implement science activities in the classroom, both teachers indicated that it was helpful for different reasons. The novice teacher stated that it provided a “springboard to implementing the curriculum” and gave her “inspiration.” The expert teacher stated that the STEAM curriculum helped her become more open-minded as to how STEAM can be incorporated throughout the curriculum. The belief that the professional development provided increased their comfort levels with implementing the STEAM curriculum was evident across pre- and post- intervention interviews and both novice and expert teachers, however both respondents indicated a desire to participate in additional professional development learning activities related to STEAM, especially with regard to how to better connect it with language arts. In particular, the expert teacher voiced a desire for more book suggestions that would help her tie literacy and STEAM together, while the novice teacher indicated a desire for increased technology integration. Finally, when asked if they thought the STEAM-based hands-on curriculum had affected their pedagogical beliefs and practices, both participants indicated that the STEAM curriculum had a positive effect in that it taught them that early childhood students need exploration and hands-on activities in order to learn science.

Self-efficacy related to STEAM curriculum

Both teachers indicated that they first became interested in the STEAM curriculum when they saw it being piloted with other teachers in their school. They saw the STEAM teachers and students engaging in very interesting investigations that aroused their curiosity about the program, especially the engineering lab, spurring them to become involved.

Both participating teachers were most enthusiastic about the technology component of the STEAM curriculum. The students utilized a class set of iPads for data collection, story writing, creating graphs, etc. The expert teacher indicated that her students looked forward to the afternoons more than any other part of the day because that was when they were participating in the STEAM program (post-interview), while the novice teacher stated that she most enjoyed “the question of the day, because we come back to it all day.” The expert teacher also stated that her students were often so engaged in what they were doing with the STEAM curriculum, that they didn’t even know they were learning (post-), while the novice teacher stated that her students had gained a much greater vocabulary thanks to the new curriculum (pre-).

To increase the science knowledge of their students, both teachers specified that they believed their students needed more opportunities to experiment with/explore science themselves, which this curriculum provided. They also felt that the STEAM curriculum provided transfer of knowledge among different settings (from the classroom where they have STEAM stations, to the science lab where they experiment, to the engineering lab where they apply what they have learned).

Belief of impact of STEAM on students

Both teacher participants stated that the STEAM curriculum taught their students problem-solving skills, and both believed that the STEAM curriculum was delivered in a more exciting way and thus was more engaging to students; this engagement also provided an opportunity for the expert teacher to analyze engagement to better understand how students learn.

Previous experience beliefs

Both teacher participants recalled their own experiences with science and math as K-12 students and both stated that those experiences were mostly teacher centered and consisted of lots of reading, note-taking and memorizing. Neither could recall significant hands-on, problem-centered explorations included in their own science instruction. Thus, they generally did not enjoy K-12 science when they were students. Prior to the implementation of the STEAM curriculum, neither the novice nor the expert teacher participants indicated that they provided hands-on science or math experiences very often for their own students. The novice teacher stated that prior to the inception of the STEAM curriculum, she had no experiences with STEAM-based science subject matter.

Predicted Findings

The researchers predicted that there would be a significant difference in science achievement between the novice and expert teachers' students, with the expert teacher's students outperforming the novice teacher's students. In addition, the researchers' predicted that the novice teacher's pedagogical beliefs and instructional strategies would demonstrate the greatest change from pre- to post- survey, indicating less of a reliance on the following: worksheets, workbooks, treats and stickers as rewards, coloring with pre-drawn forms, individual work assignments, and repetition and recitation and a greater emphasis on planning activities that interest the students, including students in planning the activities, providing daily opportunities to develop social skills, and providing more opportunities for playing with games, puzzles and construction materials, etc.

Findings

Student Assessment Findings (pre-post)

For the students in the novice teacher's class, findings of the paired t-test indicated there was a statistically significant mean difference in student achievement from pre- to post-scores (Mean difference = 2.2 points) following the intervention, t (18) = -4.282, $p < .001$, d = .91 (large effect), r2 = .171. The hands-on learning activities had a large effect on the achievement of the treatment teachers' students and 17.1% of the variance can be attributed to the intervention.

Findings of the paired t-test for students in the expert teacher's class also indicated there was a statistically significant mean difference in student achievement from pre- to post-scores (mean difference = 3.8 points) following the intervention, t (16) = -7.307, $p < .001$, d = 1.39 (large effect), r2 = .326. Thus, the hands-on learning activities had a large effect on the achievement of the treatment teachers' students and 32.6% of the variance can be attributed to the intervention.

Findings of the independent t-test indicated there was not a statistically significant mean difference in student achievement between the novice and expert teachers following the intervention, t (34) = -.752, p .457.

Teacher Beliefs and Practices Survey

The findings from the Teacher Beliefs and Practices Survey indicated that as a result of the STEAM experience, 47.6% (20 out of 42) of the novice teacher's survey responses changed from pre- to post- intervention. For example, these items increased from fairly important to extremely important: (1) the use of books, pictures, and materials in the classroom to include people of different races, ages, and abilities and both genders in various roles, and (2) the integration of each child's home culture and language into the curriculum throughout the year. The following items decreased from extremely important to very important for the novice teacher: (1) use of treats, stickers, and/or stars to get children to participate in activities that they really didn't want to engage in, and (2) the development of an individualized behavior plan for severe behavior problems.

The expert teacher's responses on the same survey indicated a 39.5% change rate from pre- to post intervention. Instruction in letter and word recognition increased from fairly important to extremely important; and coloring with pre-dawn forms changed from fairly important to not at all important. The use of one approach for reading and writing instruction decreased from fairly important to not very important. The use of activities responsive to individual children's interests along with activities responsive to the cultural diversity of students decreased from very important to fairly important. Finally, following a prescribed curricular plan decreased from very important to fairly important.

Sixteen out of thirty (53.3%) of the novice teacher's responses changed from pre- to post intervention regarding instructional strategies. For example, the novice teacher indicated a change from rarely to very often regarding the use of rewards as incentives to participate in classroom activities and incorporating multiple subject areas into her instruction. Increasing from sometimes to very often were the following: addressing students' race, culture and language in the classroom, solving real math problems using real objects in the classroom, and separating children from their friends to maintain classroom order. Several of the novice teacher's instructional strategy beliefs decreased from pre- to post intervention including circling, underlining and/or marking items on worksheets (decreased from regularly to almost never); coloring, cutting and pasting pre-drawn forms (decreased from very often to rarely); using commercially prepared phonics activities (decreased from very often to sometimes); and, practicing handwriting on lines (decreased from regularly to rarely).

In comparison, 60% (18 out of 30) of the expert teacher's survey responses regarding instructional strategies changed from pre-to post intervention. For example, exploring science materials (e.g., animals, plants, wheels, gears, etc.) increased from sometimes to very often while using flashcards with ABCs, using sight-words, and or using math facts decreased from rarely to sometimes. In addition, the use of commercially prepared phonics activities decreased from sometimes to rarely while the use of coloring, cutting, and pasting pre-drawn forms changed from rarely to almost never. Finally, participating in rote counting changed from very often to regularly.

Discussion

Data analysis of the students' pre-post test scores in both the novice and expert teacher's classes indicated a significant mean difference in student achievement from pre- to post-scores (mean difference = 3.8 points) following the intervention, $t(16) = -7.307$, $p < .001$, $d = 1.39$ (large effect), $r2 = .326$. The researchers predicted this finding and attributed this significant learning gain on the utilization of the hands-on science activities. With regard to RQ1, the independent t-test indicated no statistically significant mean difference in student achievement between the novice and expert teachers' students following the intervention, which was a finding that was not predicted by the researchers and was contradicted by the research literature. For example, Hattie's (2003) study indicated that students who have expert teachers tend to understand content at a higher level and demonstrate more advanced achievement than their counterparts in the classes of novice teachers. It is possible that the small class sample size may have negatively impacted this outcome, as small sample size tends to decrease the power of a study, increase its margin of error and result in less conclusive findings. However, since the majority of this study was qualitative in nature, it would have been much more difficult to include additional classes and teachers. In addition, this study was not meant to quantify the general performance of the novice teacher's and expert teacher's students, but was intended to document the existence of the effect.

With regard to RQ2, both the novice and expert teachers' responses to focus interview questions indicated that for the most part, the STEAM based hands-on science activities positively impacted their pedagogical beliefs and practices. For example, both novice and expert teachers indicated reductions in the use of direct instruction and prescribed curricular activities which would be expected with professional development geared toward inquiry-based instruction. This correlates to experiences described by Cotabish, et al., 2011; Herro & Quigley, 2016; Hyunju, et al., 2016; Li, et al., 2016 and Nadelson, et al., 2013. The survey responses of the novice teacher also demonstrated an increase in the utilization of cultures and cross curricular topics relevant to the students following the intervention. This finding can be tied to the use of real-world problem solving as discussed by Herro & Quigley, 2016; Cotabish, et al., 2016; and Li, et al., 2016. The novice teacher also displayed a reduced tendency to utilize rewards and behavior plans post- intervention, which can be tied to more self-efficacy and a more positive attitude transferred to the students as discussed by Nadelson, et al. (2013).

In addition, when tied to beliefs, one would expect to find an increase in the utilization of instructional strategies tied to cultures and the integration of multiple subject areas relevant to the students for real-world problem solving, which is supported by the findings of Herro & Quigley, 2016; Cotabish, et al., 2016). Contradicting this pattern was the increase of the use of rewards and behavior plans (separation of friends) used in instructional strategies by the novice teacher when it was reduced in pedagogical belief. Hyunju, et al. (2016) and Nadelson (2013) describe this as a known gap between perception and implementation that needs to be further explained. The expert teacher's increase in the use of exploration in instructional strategies is teamed with a reduction in pedagogical belief in direct instruction. This is related to the use of group collaboration and reductions in direct instruction explored by Herro and Quigley (2016).

With regard to RQ3, the professional development provided (GUW) proved to be an overwhelmingly positive learning experience for both the expert and novice teachers, one that enabled them to provide science experiences for their students that ultimately allowed for increased vocabulary attainment, increased utilization of cross-disciplinary concepts, better retention of science content, the development of problem-solving skills, and increased transfer of scientific knowledge among settings.

Implications

The findings of this research project have implications for teachers at all levels of experience, school administrators, and students. For teachers, the study provides a clear picture of the differences between expert and novice teachers, and from those differences novice and expert teachers might better be able to identify areas of pedagogical weaknesses among novice teachers so that novice teachers might seek to improve in those areas and expert teachers could become more aware of the needs of novice teachers, especially for those who are involved in mentoring relationships with less experienced teachers. In addition, this study could impact the professional development decisions of both expert and novice teachers, especially those interested in implementing STEAM into their curricula. Moreover, school administrators could use this study's findings for making professional development decisions, for pairing new teachers with mentors, and for STEAM curricular choices. Finally, students could benefit from the findings because their academic achievement is partially dependent on teacher expertise and teacher knowledge.

Conclusion

In conclusion, the GUW Professional Development provided for the participating teachers resulted in a significant mean difference in their students' achievement from pre- to post- assessment. It also positively impacted the pedagogical beliefs and practices of both the novice and expert teachers. Surprisingly, there was no significant mean difference in student learning gains post intervention between the novice and expert teachers' classes. The researchers suspect that the small sample size might have impacted this finding and suggest that if quantifying the performance of students is the intention, it be increased in a replicated study.

References

Almarza, G. (1996). Student foreign language teachers' knowledge growth. In D. Freeman & J. Richards (Eds.). *Teacher learning in language teaching* (pp. 50-78). Cambridge University Press.

American Forest Foundation (2013). Project Learning Tree Environmental Education Guide Pre-K-8. Washington DC: American Forest Foundation.

Barmald, R., Hardman, F., & Leat, D. (1995). Initial teacher trainees and their views of teaching and learning. *Teaching and Teacher Education, 11*(1). 23-31. doi: 10.1016/0742-051X(94)E0009-T

Bereiter, C., & Scardamalia, M. (1993). *Surpassing ourselves: An inquiry into the nature and implications of expertise.* La Salle, IL: Open Court.

Binnie-Smith, D. (1996). Teacher decision making in the adult ESL classroom. In D. Freeman & J. Richards (Eds.), *Teacher Learning in Language Teaching* (pp. 197-216). New York: Cambridge University Press.

Brandwein, P. (1995). Science talent in the young expressed within ecologies of achievement (RBDM 9510). Storrs, CT: The National Research Center of the Gifted and Talented, University of Connecticut.

Breen, M. (1991). Understanding the language teacher. In R. Phillipson, E. Kellerman, L. Selinker, M. Sharwood-Smith, & M. Swain, (Eds.), *Foreign/second language pedagogy research* (pp. 213-233). Clevedon: Multilingual Matters.

Callahan, M., & Oakes, L. (1992). Preschoolers' questions and parents' explanations: Causal thinking in everyday activity. *Cognitive Development, 7*(2), 213-233. doi:10.1016/0885-2014(92)90012-g

Clancey, W. (1997). *Situated cognition: On human knowledge and computer representation.* Cambridge: Cambridge University Press.

Chase, W. & Simon, H. (1973). The mind's eye in chess. In W. Chase (Ed.), *Visual information processing* (pp.215-281). New York: Academic Press.

Chatterji, M. (2004). Evidence on "What Works": an argument for extended-term mixed-method (ETMM) evaluation designs. *Educational Researcher, 34*(5), 14-24. doi:10.3102/0013189X034005014

Clancey, W. (1997). *Situated cognition: On human knowledge and computer representation.* Cambridge, U.K;: Cambridge University Press.

Cohen, M., Kahn,D., & Steeves, R. (2000). *Hermeneutic Phenomenological Research: A Practical Guide for Nurse Researchers.* Thousand Oaks, CA: Sage Publications.

Cotabish, A., Dailey, D., Robinson, A., & Hughes, A. (2013). The effects of a STEM intervention on elementary students' science knowledge and skills: The effects of a STEM intervention. *School Science and Mathematics, 113*(5), 215-226. doi:10.1111/ssm.12023

Delaney, M. (2014). *Schools shift from STEM to STEAM*. EdTech, 1-4. Retrieved from http://www.edtechmagazine.com/k12/article/2014/04/schools-shift-stem-steam

Dewey, J. (1916). *Democracy and Education: An Introduction to the Philosophy of Education.* New York: Macmillan.

Dinour, L., Kwan, A., & Freudenberg, N. (2017). Use of comparative case study methodology for US public health policy analysis: A review. *Journal of Public*

Health and Managing Practice, 23(1), 81-89. doi:10.1097/ phh.0000000000000406

Duschl, R., Schweingruber, H., & Shouse, A. (2007). *Taking science to school: Learning and teaching science in grades K-8.* Washington, DC: National Academies Press.

Eggers, T. (2007). *Hands-on science for young children.* Early childhood News. Retrieved from http://www.earlychildhoodnews.com/earlychildhood/article view. aspx?ArticleID=431

Fosnot, C. (1996). Constructivism: A psychological theory of learning. In *Constructivism: Theory, Perspectives, and Practice,* (pp. 8-33). New York: Teachers College Press.

Gatbonton, E. (1999). Investigating experienced ESL teachers' pedagogical knowledge. *Modern Language Journal, 83*(1), 35-50. doi:10.1111/0026-7902.00004

Glaser, B. & Strauss, A. (1967). T*he discovery of grounded theory: Strategies for qualitative research.* New York: Aldine Publishing Co.

Glaser, R., & Chi, M. (1988). Overview. In M. Chi, R. Glaser, & M. Farr (Eds.), *The nature of expertise* (pp. xv-xxviii). Mahwah, NJ: Lawrence Erlbaum Associates.

Goldstein, D. (2005). Elementary science: Left behind? *Journal of Science Teacher Education, 16*(3*)*, 185-187. doi:10.1007/s10972-005-4859-8

Growing up WILD: exploring nature with young children. (2009). Houston, TX: Council for Environmental Education.

Haney, J. & McArthur, J. (2002). Four case studies of prospective science teachers' beliefs concerning constructivist teaching practices. *Science Education, 86*(6), 802;783;-802. doi:10.1002/sce.10038

Happo, I. ,Maatta, K., & Uusiautti, S. (2013). How do early childhood education teachers perceive their expertise? A qualitative study of child care providers in Lapland, Finland. *Early Childhood Education Journal, 41*(4), 273-281. doi:10.1007/ s10643-012-0551-8

Hattie, J. (2003). *Teachers make a difference: What is the research evidence?* Paper presented at the Australian Council for Educational Research Annual Conference on Building Teacher Quality, Melbourne, Victoria, Australia.

Herro, D., & Quigley, C. (2016). Innovating with STEAM in middle school classrooms: Remixing education. *On the Horizon, 24*(3), 190-204. doi: 10.1108/OTH-03-2016-0008.

Hyunju Park, H., Soo-Yong, C., Jaeho, S., Hyesook, H., & Yoon Su, B. (2016). Teachers' perceptions and practices of STEAM Education in South Korea. *Eurasia Journal of Mathematics, Science & Technology Education, 12*(7), 1739-1753. doi:10.12973/Eurasia.2016.1531a

Johnson, K. (1992). The Relationship between Teachers Beliefs and Practices during Literacy Instruction for Non-Native Speakers of English. *Journal of Reading Behavior, 24*(1), 83-108. doi:10.1080/10862969209547763

Johnston, B. & Goettsch, K. (2000). In Search of the Knowledge Base of Language Teaching: Explanations by Experienced Teachers. *Canadian Modern Language Review, 56*(3), 437-468. doi:10.3138/cmlr.56.3.437

Johnson, C., Kahle, J., and Fargo, J. (2006). Effective teaching results in increased science achievement for all students. *Science Education, 91*(3), 371-383. doi:10.1002/sce.20195

Kang, M., Park, Y., Kim, J., & Kim, Y. (2012). Learning outcomes of the teacher training program for STEAM education. *The Korean Journal of the Learning Sciences.* (7)2, 18-28. Retrieved from http://www.dbpia.co.kr/Journal/ArticleDetail/NODE02238785

Keely, P. (2009). Elementary science education in the K-12 system. Elementary science education in the K-12 system. (guest editorial). *Science and Children, 46*(9), 8-9.

Kelchtermans, G. (1993). Getting the story, understanding the lives: From career stories to teachers professional development. *Teaching and Teacher Education, 9*(5-6), 443-456. doi:10.1016/0742-051x(93)90029-g

Kim, Kyung-Ran (2005). *Teachers' beliefs and practices survey: Operationalizing the 1997 NAEYC guidelines.* (Unpublished doctoral dissertation). Louisiana State University and Agricultural and Mechanical College, Baton Rouge, LA.

Li, Y., Huang, Z., Jiang, M., & Chang, T. W. (2016). The effect on pupils' science performance and problem-solving ability through lego: An engineering design-based modeling approach. *Journal of Educational Technology & Society, 19*(3), 143-156.

Lott, K., Wallin, M., Roghaar, D., and Price, T. (2013). Engineering encounters: Catch me if you can. *Science and Children, 51*(4), 65-69. doi:10.2505/4/sc13_051_04_65

MacDonald, A., Huser, C., Sikder, S. & Danaia, L. (2019). Effective early childhood STEM education: Findings from the *Little Scientists Evaluation. Early Childhood Education Journal, 48,* 353-363. doi: 10.1007/s10643-019-01004-9

Marshall, C. & Rossman, G. (1999). *Designing Qualitative Research.* Thousand Oaks, CA: Sage Publications.

Masata, D. (2014). Understanding the STEM skills gap. STEM Education News. Retrieved from http://www.educationandcareernews.com

Merriam, S. B. (1988). *Case study research in education: A qualitative approach* (First ed.). San Francisco: Jossey-Bass.

Meyer, H. (2004). Novice and expert teachers' conceptions of learners' prior knowledge. *Science Education, 88*(6), 970-983. doi:10.1002/sce.20006

Michaels, S., Shouse, A., & Schweingruber, H. (2008). Ready, set, science! Putting research to work in K-8 science classrooms. Washington DC: The National Academy Press.

Moonaw, S., & Davis, J. (2010). STEM comes to preschool. *YC Young Children, 65*(5), 12-18.

Nadelson, L. S. (2013). Who is watching and who is playing: Parental engagement with children at a hands-on science center. *The Journal of Educational Research, 106*(6), 478-484. doi:10.1080/00220671.2013.833010

Nadelson, L.S., Callahan, J., Pyke, P., Hay, A., Dance, M., & Pfiester, J. (2013). Teacher STEM perception and preparation: Inquiry-based STEM professional development for elementary teachers. *The Journal of Educational Research, 106*(2), 157-168. doi:10.1080/00220671.2012.667014

NAEYC (1997). Guidelines for the preparation of early childhood professionals. Washington DC: Author.

National Science Board (2010). *Preparing the next generation of STEM innovators: Identifying and developing our nation's human capital.* (NSB Publication No. NSB-10-33). Arlington, VA. Available at: http://www.nsf.gov/nsb/publications/2010/nsb1033.pdf

NSTA position statement: Early childhood science education. (2014). *Science and Children*, *51*(7), 10-12.

Parette, H., Quesenberry, A., & Blum, C. (2010). Missing the boat with technology usage in early childhood settings: A 21st century view of developmentally appropriate practice. *Early Childhood Education Journal*, 37, 335-343.

Peterson, P. & Comeaux, M. (1987). Teachers schemata for classroom events: The mental scaffolding of teachers thinking during classroom instruction. *Teaching and Teacher Education, 3*(4), 319-331. doi:10.1016/0742-051x(87)90024-2

Piaget, J., & Cook, M. T. (1952). *The origins of intelligence in children.* New York, NY: International University Press.

Porter, A. (1997). Comparative experiments in educational research. In Jaeger, R. (Eds.), *Complementary methods for research in education* (2nd ed.), (pp.523-547). Washington D.C.: American Educational Research Association.

Pratt, H. (2007). Science education's "overlooked ingredient". Why the path to global competitiveness begins in elementary school. *Education Week*, *27*(7). Retrieved from https://www.edweek.org/ew/articles/2007/10/10/07pratt.h27.html

Quigley, C., Herro, D. & Jamil, F. (2017). Developing a conceptual model of STEAM teaching practices: Developing a conceptual model. *School Science and Mathematics, 117*(1-2), 1-12. doi:10.1111/ssm.12201

Rich, Y., & Almozlino, M. (1999). Educational goal preferences among novice and veteran teachers of sciences and humanities. *Teaching and Teacher Education,15*(6), 613-629. doi:10.1016/s0742-051x(99)00010-4

Richards, J., Li, B. & Tang, A. (1998). Exploring pedagogical reasoning beliefs. In J. C. Richards (Ed.), *Beyond training*. New York: Cambridge University Press.

Robinson, A., Dailey, D., Hughes, G. & Cotabish, A. (2014). The effects of a science-focused STEM intervention on gifted elementary students' science knowledge and skills. *Journal of Advanced Academics*, *25*(3), 189-213. doi:10.1177/ 1932202X14533799

Selinger, E., & Crease, R. (Eds.). (2006). *The Philosophy of Expertise*. New York, NY: Columbia University Press.

Simoncini, K., & Lasen, M. (2018). Ideas about STEM among Australian early childhood professionals: How important is STEM in early childhood education? *International Journal of Early Childhood, 50*, 353-369. Doi: 10.1007/s13158-018-0229-5

Sing, C. (2010). Teachers' epistemic beliefs and their pedagogical beliefs: A qualitative case study among Singaporean teachers in the context of ICT-supported reforms. *TOJET: The Turkish Online Journal of Educational Technology, 9*(4). 128-139.

Taylor, S. & Sobel, D. (2001). Addressing the discontinuity of students' and teachers' diversity: a preliminary study of preservice teachers' beliefs and perceived skills. *Teaching and Teacher Education*, *17*(4), 487-503. doi:10.1016/s0742-051x(01)00008-7

Tippett, C. D. & Milford, T. M. (2017). Findings from a pre-kindergarten classroom: Making the case for STEM in early childhood education. *International Journal of Science and Mathematics Education, 15.*doi: 10.1007/s10763-9812-8

Trundle, K. C. (2010). Teaching science during the early childhood years. National Geographic.

Tsui, A. (2003). *Understanding expertise in teaching: Case studies of ESL teachers.* New York: Cambridge University Press.

Tsui, A. (2005). Expertise in teaching: Perspectives and issues. In Johnson, K. (Ed.), *Expertise in second language learning and teaching* (pp. 167-189). New York: Palgrave Macmillan.

Tsui, A. (2009). Distinctive qualities of expert teachers. *Teachers and Teaching, 15*(4), 421-439. doi:10.1080/13540600903057179

Verloop, N., Van Driel, J. & Meijer, P. (2001). Teacher knowledge and the knowledge base of teaching. *International Journal of Educational Research, 35*(5), 441-461. doi:10.1016/S0883-0355(02)00003-4

Vygotsky, L. (1978) *Mind and society: The development of higher psychological processes.* Cambridge, MA: Harvard University Press.

Williams, L. (2013). Should STEM become STEAM? *District Administration, 49*(2), pp. 22. Retrieved from https://www.districtadministration.com/article/should-stem-become-steam

Wolff, C. E., van den Bogert, N., Jarodzka, H., &Boshuizen, P. (2015). Keeping an eye on learning: Differences between expert and novice teachers' representations of classroom management events. *Journal of Teacher Education, 66*(1), 68-85. doi:10.1177/0022487114549810

Wolff, C. E., van den Bogert, N., Jarodska, H., &Boshuizen, P. (2016). Teacher vision: expert and novice teachers' perception of problematic classroom management scenes. *Instructional Science, 44,* 243-265. doi: 10.1007/s11251-016-9367-z

Wood, E., & Bennet, N. (2000). Changing theories, changing practice: exploring early childhood teachers' professional learning. *Teaching and Teacher Education, 16*(5-6), 635-647. doi:10.1016/s0742-051x(00)00011-1

Yin, R. K. (1994). *Case study research: Design and methods.* (2nd ed.). Thousand Oaks, CA: Sage, 1994.