EFFECTS OF A WATER CONSERVATION EDUCATION PROGRAM ON WATER USE IN SINGLE-FAMILY HOMES IN DALLAS, TEXAS

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The City of Dallas Environmental Education Initiative (EEI) is a hands-on, inquiry-based, K-12 water conservation education program that teaches students concepts about water and specific water conservation behaviors. Few descriptions and evaluations, especially quantitative in nature, of water conservation education programs have previously been conducted in the literature. This research measured the quantitative effects and impacts of the education program on water use in single-family homes in Dallas, Texas. A total of 2,122 students in 104 classrooms at three schools in the Dallas Independent School District received hands-on, inquiry-based water conservation education lessons and the average monthly water use (in gallons) in single-family homes was analyzed to measure whether or not there was a change in water use. The results showed that over a period of one calendar year the water use in the single-family homes within each school zone and throughout the entire research area in this study experienced a statistically significant decrease in water use of approximately 501 gallons per home per month (independent, t-test, p>0.001).

Data from this research suggests that EEI is playing a role in decreasing the amount of water used for residential purposes. Additionally, this research demonstrates the use of a quantitative tool by which a water conservation education program’s effect on behavior change can be measured. This research shows great promise for reducing use and increasing the conservation of our world’s most precious resource.
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By

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CHAPTER 1
INTRODUCTION

Background

“We do not have enough existing water supplies today to meet the demand for water during times of drought” (Texas Water Development Board, 2012, p. 4).

Population and economic growth, lifestyle changes, and periodic drought have increased water demand globally and locally (Bates et al., 2008; Kenny et al., 2009).

The recognition that droughts are common in the state of Texas is important in the discussion of water conservation practices and strategies. As reported by the Texas Water Resources Institute (2011a), Texas has suffered many droughts in its history. A decade of extreme dryness and decrease in precipitation happened in the 1950s, following the famous Dust Bowl events of the 1930s. Towards the end of 1956, 254 of the 255 counties in Texas were considered disaster areas.

It was because of that “drought of record” that the Texas legislature created the Texas Water Development Board (TWDB) and the Water Planning Act of 1957 in an effort to prevent future devastating effects of drought and to plan for future water needs in the state. The TWDB created the first state water plan in 1961, which marked the beginning of the water planning process and policy recommendations in the state (Texas Water Resources Institute, 2011a). In 1997 the legislature passed Senate Bill 1, which reorganized the planning process to encompass a more “bottom-up” approach that included 16 regional planning districts, each creating its own regional water plan every five years and submitting it to the TWDB (Texas Water Resources Institute, 2011b; Texas Water Development Board, 2012). The regional water plans include ten
major tasks, which include a description of the area, population and water demand projections, current water supplies, needs, policy recommendations, impacts on water quality, finance, and finally water management strategies to meet future needs. In addition, it is within the management strategies that each plan must include information about public outreach and education.

Figure 1. Region C planning district.

Note: From *TWDB Maps*, Texas Water Development Board, January 2014
The area commonly referred to as North Central Texas is located within the Region C planning district (see Figure 1). The population and water consumption in North Central Texas has been increasing as more people flock to the urban areas, with a projected population of 10.5 million by 2040 (North Central Texas Council of Governments, 2012). More specifically, population in 2013 in the City of Dallas was estimated by the North Texas Council of Governments to be 1,213,600 and is projected to be 1,841,064 by 2060 (Dallas Water Utilities, 2014, p.10). Water consumption per capita in the City of Dallas is among the highest in the state of Texas (Dallas Water Utilities, 2006) with a historic five-year average of 101 gallons per capita per day for residential use in fiscal year 2012-2013 (Dallas Water Utilities, 2014). Conservation measures in Dallas and the state of Texas, such as efficient management, rebate and incentive programs, and outreach and education, have been employed to ensure that future water demands will be met.

In the Texas Administrative Code (1993), the minimum requirements for water conservation plans include “a program of continuing public education and information regarding water conservation” 30 Tex. Admin. Code § 288.2(a). In the 2006 Region C Water Plan, public/school education was identified as a feasible water conservation strategy that met federal and state regulations (Texas Water Development Board, 2006). The report stated, “public and school education programs conserve water by teaching water-conserving behavior to water customers and reinforcing such behavior through periodic reminders” and “school education programs provide water conservation curriculum material at appropriate grade levels,” with an indirect benefit of information transfer from child to parent (Texas Water Development Board, 2006,
The process of information reaching parents through children, or intergenerational transfer, is discussed further in Chapter 2.

Dallas Water Utilities Conservation Outreach and Education

Alan Plummer Associates, Inc (2010) reported in the City of Dallas Water Conservation Five-Year Strategic plan that the City of Dallas recognized a need for water conservation in the 1980s. Conservation efforts in Dallas began with special events, brochures, water bill inserts, speaking engagements and children’s poster contests. Following the initial efforts, the city focused on media relations, special events, classroom presentations by staff members, retrofit programs for residential homes, and landscape exhibits, seminars, and tours in partnership with the Texas Agricultural Extension Services. In 2001 Dallas implemented watering restrictions that prohibited, and continue to prohibit, watering between 10:00 am and 6:00 pm from April 1 through October 31. In 2002 the city also adopted a multimedia public awareness campaign to educate citizens and customers about the water restriction ordinance and other landscape irrigation techniques. A year later, the city expanded its summer education outreach initiatives to include recreation centers and created a website with information about programs, ways to save water, and frequently asked questions about water conservation. The City of Dallas Environmental Education Initiative (EEI) was created in fiscal year 2005-2006 and called for lesson development, school-based education, a K-5 outreach event, and teacher workshops. The City of Dallas issued a request for proposal (RFP) and it was the city’s first attempt at creating a unified message of environmental education in schools. Through collaboration between Dallas Water Utilities (DWU) and the Department of Sanitation, the EEI sought to provide water
conservation and recycling education to students in school districts within the city limits. The original scope of work and 3-year contract was awarded to a collaborative team from Hamline University in St. Paul, Minnesota and the University of North Texas (UNT) in Denton, Texas in 2005 and implementation of the program began no later than January 16, 2006. During the first 3-years of the program, from 2005-2008, the EEI served over 23,000 students in school-based programs, 6,600 participants in community events and appearances, and 688 teachers in professional development workshops. In 2008, the City of Dallas put out another RFP, built upon and around the previous work and objectives of the initial contract. The city was seeking a contractor to continue the work of the EEI and Dr. Ruthanne Thompson, a researcher and professor of science education in the Department of Biology at UNT, was awarded the second contract for a period of 5 years, from 2008 – 2013. Dr. Thompson was part of the original team who was awarded the initial 3-year contact from 2005 – 2008. During the second contract, the EEI served over 110,000 students in school-based programs, approximately 20,300 participants in community events and appearances, and approximately 1,200 teachers in professional development workshops.

In 2009, DWU partnered with Tarrant Regional Water District to maximize its public awareness campaign budget and to provide a uniform water conservation message, because the Dallas-Fort Worth area is a single media market and customers receive messages from multiple water providers (Alan Plummer and Associates, Inc, 2010). The Dallas Water Utilities’ City of Dallas Water Conservation Plan (2014) stated that “the City of Dallas’ public education program is considered one of the best information and education programs in the State of Texas” (p. 17), winning multiple
awards for both the public and school programs. Also reported was the budget for the public awareness campaign and the EEI. The budget for the public awareness campaign increased from $1,150,000 in fiscal-year 2003-2004 to $1,320,000 in fiscal-year 2012-2013. The budget for the EEI also increased from $171,000 in fiscal-year 2005-2006 to $274,000 in fiscal-year 2009-2010 (Dallas Water Utilities, 2014, p. 18). It is interesting that the public awareness budget was approximately five times greater than the budget for the school and community education program. Results of this study may give water conservation managers quantitative data as to whether or not the EEI is effective in changing water use behavior, which can aid in the development and appropriation of funds for education in future years.

The City of Dallas put out a third RFP in early 2013, which would extend the EEI program for five additional years. UNT and a private business were the only bidders who submitted a proposal to continue EEI. For the third time in a row, veteran EEI director and UNT professor, Dr. Ruthanne Thompson received the third, multi-year contract from the City of Dallas in October 2013. Dr. Thompson’s EEI team increased in number in order to accommodate the new contract requirements, which would include a renovation of the scheduling calendar, website, and database management system. The new contract also included a brand new social media outreach campaign, a revised high school program called Team WaterWorks, and an increase in the amount of students, teachers, and community members served. The new EEI team consisted of a program coordinator (also a certified teacher), an outreach coordinator (also a certified teacher), environmental science graduate students (also certified teachers) seeking advanced degrees with an emphasis in science education, and undergraduate students
pursuing degrees in education and the fields of science, technology, engineering, and mathematics (STEM). The team will implement EEI for the next five years, from 2013 – 2018 and continue to reach more students, teachers, and community members. A more detailed and up-to-date description of the current EEI is provided in the following section.

City of Dallas Environmental Education Initiative (EEI)

The EEI was created in fiscal year 2005-2006, when DWU augmented its school education programs and collaborated with the Department of Sanitation. According to the official RFP sent out by the city in the summer of 2005, the EEI was to be funded by both departments to provide water conservation and recycling education to students who lived in the City of Dallas and who attended local independent school districts (ISDs). The contractor who would be awarded with the initial 3-year contract would recruit community partners, gain approval from ISD officials to provide water conservation and recycling curriculum in classrooms, develop and host teacher training workshops, and would maintain an interactive scheduling website (http://dallaseei.org) where teachers could select and schedule lessons. Results from the first year of implementation in 2005-2006 would determine the goals and objectives that would be set in the second and third year of the contract. The implementation of a unified, environmental education message and presence in schools was a novel concept for the City of Dallas at the time. It was also a novel approach for the city to seek a contractor to perform education and outreach, rather than provide its own staff to do the work (R. Thompson, personal communication, April 23, 2014).
The initial RFP from the City of Dallas outlined specific project objectives which the contractor would have to follow which included:

- Creating Department of Sanitation education content
- Including specific content and facts relating to the City of Dallas DWU because it served as a major component of the program (population served, ordinances, water sources, and treatment processes)
- Creating and maintaining a scheduling website and calendar
- Age and grade-appropriate lessons aligned to the Texas Essential Knowledge and Skills (TEKS) geared to fit within ISD time allotments
- Strategies to encourage teacher participation
- Providing at least 28 in-class presentations that occurred in at least 14 elementary schools, representing each council district
- Providing, planning, and developing, at least 10 teacher professional development workshops
- Creating supplemental lesson materials and activities for teachers in the event that presentation resources were not available
- Developing and implementing one community outreach event for K-5
- Developing monthly, quarterly, and annual reports and data which would reflect each component of the program and the number of participants served

The team from Hamline University and UNT, the only universities who submitted a bid for the EEI, proposed a plan that not only met the RFP objectives but exceeded the city’s requirements. For example, the team proposed an increase in the number of lessons they would teach (56 instead of 28). The team proposed creating lessons and
content that was aligned with the TEKS and Texas Assessment of Knowledge and Skills (TAKS), including lesson extension activities such as CD ROMs, and hosting field trips in lieu of some classroom presentations to local water sources, treatment plants, and landfills so that students would be immersed in real-life experiences relating to water conservation and recycling. The team was going to create a recycling curriculum based on a model program from Tucson, Arizona called Too Good to Throw Away. The water curriculum would be based on lessons developed by classroom teachers for the UNT EcoPlex website (R. Thompson, personal communication, April 23, 2014) and Hamline University’s Waters to the Sea education program, but would include facts and concepts specific to DWU and the City of Dallas. The middle school lessons would also be based upon the above mentioned education programs and lessons, but would incorporate the use of handcrafted, museum-quality, hands-on, and interactive modules which would be taken to middle schools. The team also proposed a systematic and scalable professional development that would incorporate field study and classroom training, with continuing involvement and support in the form of an interactive website. As an incentive to teachers, the Hamline and UNT team also proposed a monetary incentive for teachers who would attend the workshops, in the form of a $50 gift certificate so that teachers could purchase additional science education materials for their classroom. Being a former high school classroom teacher for 20 years, before pursuing a career in higher education, Dr. Thompson recognized the need to support and reward teachers for their commitment to their students. Finally, the team proposed a K-6 education event called the Trinity River Fair, which was open to all schools that participated in the EEI. The team, Dr. Ruthanne Thompson, who was the director of the Lewisville Lake
Environmental Learning Area, and Tracy Fredin, director of the Center for Global Environmental Education, was awarded the first EEI contract for a period of 3-years, which was contingent upon the evaluation of the first year. As mentioned previously, during the first contract period, the EEI served over 23,000 students in school-based programs, 6,600 participants in community events and appearances, and 688 teachers in professional development workshops.

The second contract issued by the City of Dallas, which occurred during 2008 – 2013, was built upon the goals, objectives, and programs established in the initial contract. The program was to provide water conservation and recycling education for Grades K – 12, professional development for teachers, and community outreach events. The benchmark goals for participation, workshops, and community events were increased in the second contract, and also increased during each consecutive contract year from 2008 – 2013. In the final year of the second contract, the EEI was required to provide a total of 300 lessons in elementary schools (150 each for water conservation and recycling), provide lessons at a minimum of 12 middle schools, host a high school internship for students, and reach 300 teachers in professional development opportunities. The EEI was also required to participate in various community events and make appearances as Dew, the DWU mascot (see Figure 2). During the second contract, the EEI staff increased from two persons to a team of 5 passionate and enthusiastic people which included a director, a program coordinator, and four graduate students who were also certified teachers for the program. The director oversaw the entire program and served as the lead instructor for the professional development workshops. The program coordinator (also a certified teacher) taught elementary
lessons, managed the calendar and scheduling website, scheduled professional
development opportunities, and supervised the other teachers. The teachers taught
lessons in elementary and middle school, supervised the high school internship
program, participated in community events, and maintained inventory and prepared for
materials for professional development workshops.

![Figure 2. Dallas Water Utilities mascot (DEW).](image)

Community events and outreach were performed during both contracts and
consisted of events developed by the EEI and events created and hosted by other
organizations, such as Earth Day in Plano, Texas and Earth Day Dallas at Fair Park in
Dallas, Texas. The EEI would maintain a booth at the events, engage in quick
educational activities with the public, and provide promotional items tied to water
conservation and recycling, such as reusable cups, shower timers, informational water
wheels with tips on how to save water, and pencils made from recycled material in order
to extend the reach of the education from the event into the home. At other times, the EEI teachers would dress-up as the DWU mascot, Dew (see Figure 2), and engage with the community at events such as National Night Out and the Turkey Giveaway and Health Care Fair in Dallas, Texas.

The professional development workshops provided by EEI were approximately 3.5 hours in length and focused on training the teachers in each of the lessons EEI had in its curriculum. In the initial contract period, during the 2006 – 2007 school year, the EEI director, Dr. Ruthanne Thompson, submitted and was granted formal approval to conduct professional developments in Dallas Independent School District (DISD). Dr. Thompson outlined the EEI curriculum using the DISD Professional Development Module Form Course Content Outline and teachers in attendance would be able to gain continuing education credits, which are required by the state to renew teacher certification. The specific TEKS and TAKS learning standards for each grade level, which were aligned with all lessons in the EEI water conservation and recycling curriculum, were outlined. The professional learning outcomes for participants were outlined as well, and included results that called for participants to have a deep understanding of the role hands-on lessons play in learning and for participants to understand the finite nature of Earth’s resources, among other goals. Maintaining the similar structure as outlined in the initial contract, the professional development workshops continued to employ inquiry and hands-on teaching methods and active participation from the participants. As the TEKS and TAKS (now the State of Texas Assessments of Academic Readiness [STAAR]), DISD scope and sequence, water
resources, recycling technology, culture of the citizenry, and requests from the City of Dallas evolved over the course of the second contract, the EEI updated its curriculum and methods to keep current and on the forefront of environmental education in Dallas.

The middle school component of the EEI consisted of students being visited by a certified teacher who brought museum-quality exhibits that contained information about water conservation and recycling, as well as videos and interactive manipulatives. The modules were available for an entire week in a central location in a school and students and teachers visited with the EEI teacher during the week for a lesson and discussion about water conservation and recycling, which included suggestions of specific behaviors that promoted water conservation, recycling, and the reduction of waste. Based on requests from DWU and the Department of Sanitation, the exhibits were also displayed at community events, museums, and other locations throughout Dallas.

During the second contract, the high school component of the EEI incorporated university-level research focused on the evaluation of the EEI’s effects on behavior of participants, specifically related to water use in single-family homes. Under the supervision of the director and teachers, the high school students assisted in the formulation of research questions, collection of data, analysis of results, and presentation of findings to staff members of DWU. Descriptions of the studies in which high school students participated in are described in chapter 3 and are part of the work that led to the formulation of the current research questions and study.

The elementary component of the EEI consisted of TEKS and TAKS-aligned (now STAAR) lessons which incorporate inquiry, hands-on activities, and take-home items and messages with current science content and facts specific to the City of
Dallas. In Grades K - 5, certified teachers conducted water conservation and recycling lessons with teachers and students in a classroom at their school and had all of the necessary teaching supplies for a hands-on activity to accompany the information. Students of this age are more concrete in thinking when engaged in learning and the hands-on lessons and activities served as a reinforcement of the behaviors and information taught (Piaget, 1964; Prince, 1999). For example, in a first grade water lesson, the students learned about the water cycle and its importance in the larger concept of water conservation. The teachers engaged the students through the steps of the cycle in the format of a song. Then, students created a water cycle necklace using different colored beads to represent different stages of the cycle like yellow for the sun, clear for evaporation, and dark blue for condensation. The concrete example of the water cycle, along with the song, served to help students remember the information and acted as a conversation piece that students could take home to share with their parents.

The EEI used in-class, hands-on lessons and specific water conservation and recycling messages about saving water and recycling to target the at-home and at-school behavior of the student participants. The combined efforts of EEI in its second year reached over 110,000 students, 1,200 teachers, and approximately 20,300 community members.

The third RFP put out by the City of Dallas occurred in early 2013 and only two bidders submitted proposals; a business and the previous contract holder, Dr. Thompson at UNT. In October of 2013 Dr. Thompson was awarded the third EEI contract for a term of five years, from 2013 - 2018. The EEI team grew once again, adding undergraduates, more graduate students, and more certified teachers. With a
team of ten passionate and motivated individuals, the EEI began to develop and update its existing methods of operation to accommodate new requirements in the contract, such as a two-fold increase in the number of lessons to be taught in schools, a new social media campaign, a new EEI certification program for schools, an updated website and reporting system, and an updated high school program called Team WaterWorks. The new EEI team is currently active and is on track to double its past number of students, teachers, and community members served.

Two important and novel components of the UNT team’s implementation of EEI are in the way the program teaches its K-12 lessons and who it employs to deliver the lessons and information. As was mentioned in the beginning of this section, the extension of an RFP for a contractor to implement the EEI was the first of its kind for the City of Dallas. Many cities with existing public education and outreach campaigns use current staff members (Brzozowski, 2011), many of whom may not have backgrounds and training in formal education, such as an accredited university teacher preparation and certification program or an alternative certification program. The EEI is innovative and progressive in that all lessons are 45-minutes in length and occur in individual classrooms in public and private schools. The EEI teachers visit with each class individually and engage in discussions, allowing less distractions and more time for the teachers to devote to each child so he or she can ask questions and get immediate answers (Mosteller, 1995). Active-learning teaching methods, such as discussions, are often used in small-group settings and are “credited with promoting critical thinking and higher-order, deep learning” (Pollock, Hamann, and Wilson, 2011, p. 49). The other important factor which differentiates EEI from other programs is that the team members
who teach lessons in K-12 are certified teachers who have been through an accredited or alternative certification program and in addition, are or have been graduate and undergraduate students engaged in scientific research in the field of environmental science education.

With this background in mind, the focus of this study involves the effects of the EEI in-class, K – 5 water conservation lessons on water use behavior in single-family homes in Dallas, Texas. The lessons covered topics such as water availability, the water cycle, the urban water cycle and water treatment processes, surface water resources and wetlands, groundwater resources and aquifers, watersheds, and water conservation behaviors and actions. During each inquiry-based, hands-on, 45-minute lesson, the EEI teachers engaged students in critical thinking about many aspects of water use, consumption practices, and conservation strategies which they would be able to employ in their homes. The Texas Education Agency (2010) TEKS include as a standard in each grade level in K-5 that students are expected to demonstrate how to use and conserve natural resources, such as conserving water. Each EEI lesson meets that standard, as well as additional related science concepts. A detailed description of each K-5 water lesson is provided next, followed by a description of the purpose of the study, research objectives, and hypotheses.

EEI K-5 Water Conservation Education Lessons for Study Year 2012-2013

Together, the EEI lessons form a spiraling curriculum (Bruner, 1960), written in such a way to complement each other as they progress from K – 5. Students are introduced to concepts in the lower grades and are reintroduced to them in later grades,
all the while also being introduced to new concepts. The following provides details on the lessons, or education, provided to each student in this study.

In kindergarten, the EEI water lesson introduced students to the concept of water quantity. Students were engaged in a discussion and hands-on activity about how much water exits on the earth, the amount of saltwater versus freshwater, and finally the amount of water available for human use and consumption. The teacher asked students to imagine that all of the water on earth could fit into a 30-gallon container. Next, the teacher pulled out a 2-gallon container, a 1-liter bottle, and a 2-oz container. With the aid of questions from the teacher, the students had to decide which container represented the amount of freshwater available for human consumption (2 oz.). Students then discussed how all living things had to share such a small amount of water and were guided in a discussion about behaviors that would ensure the conservation of that water, such as taking short showers and turning off the water while brushing their teeth. Then, students received a small, six-ounce cup and labeled it with the phrase “Save Water” on a sticker. Finally, the students and EEI teacher engaged in a drama activity to practice the use of the cup as a water conservation device for their bathroom. Students were instructed to fill their cup prior to brushing their teeth, making sure the water was turned off when the students began brushing. The students would use the water in their cup to rinse their mouth and clean their tooth brush upon completion of brushing their teeth. The cup became a take-home item for the students so they could continue their new water-saving skill at home and teach their family how to use a small, six-ounce cup of water to brush their teeth. When the students sit the cup on their bathroom counter, it serves as a reminder to them about brushing their teeth, but also
serves as a talking-point for students to explain to their parents how the cup is to be used and how it helps the student and family save water at home.

In first grade the students revisited the concept of water quantity and availability by first coloring in a 100-square grid according the amount and type of water on the earth. Ninety-seven squares represented salt water, two squares represented frozen freshwater, and one square represented the amount of water available for human use. Then, the EEI teacher and students transitioned to learning about the hydrologic cycle using a classroom discussion, song, and creation of a bracelet using beads. The song lyrics were sung to the tune of “Oh My Darling” and are as follows:

Evaporation, condensation, precipitation falling down. That’s what’s called the water cycle and it keeps on goin’ round! (Thompson et al., 2011).

A total of six beads were used in the creation of the bracelet, each bead was a different color to represent each part of the water cycle. A yellow bead represented the sun, as the sun is the driving force of the water cycle. Evaporation, condensation, precipitation, the ground, and plants (transpiration) were represented by a clear, dark blue, light blue, brown, and green bead, respectively. The EEI teacher led students in a discussion of the important of the hydrologic cycle for living things and probed students' knowledge about how water conservation related to the cycle. The TEKS also required that the hydrologic cycle be taught at this grade level. Students were guided in a discussion about water being “trapped” in the cycle, such as in the atmosphere or plants, and the impact of drought on precipitation. The EEI students were told about how Dallas gets its water, which comes primarily from five surface water reservoirs: Grapevine, Lewisville, Ray Hubbard, Ray Roberts, and Tawakoni (Dallas Water Utilities, 2012). Many of the
students were familiar with the concept of a drought, as Texas is frequently in some form of a drought, and could state that lake levels in Dallas would decrease if there was no form of precipitation. They were usually able to articulate that less water in the reservoirs meant less water for the citizens of Dallas. That discussion then led to a discussion about specific water conservation behaviors students could employ at home, such as turning the water off when they brushed their teeth or taking shorter showers. The students review the hydrologic cycle and the EEI teacher encourages students to take home their bracelet and show it to their parents. From personal experience, many times parents have asked students about their day at school and the students have often replied with shrugged shoulders and a response that indicated nothing happened. The water cycle bracelet served to aid students in having a hands-on manipulative and as an example to encourage discussion between the child and adult about water and water conservation.

In second grade, the students in this study first revisited the concepts of water quantity and the hydrologic cycle and are introduced to the concept of an urban water cycle. In the City of Dallas, the primary components of the urban water cycle consist of reservoirs, the Trinity River, water treatment and wastewater treatment plants, and student homes. The students were led in a discussion of the urban water cycle and then engaged in a kinesthetic model of the cycling using hand movements to represent each component of the cycle. Finally, the students participated in an experiment to clean “dirty” water like a scientist and engineer would at a wastewater treatment plant. The students follow procedures to add a flocculent (alum) to the water, prepare a filter, and pour the dirty water through the filter. The end result of the experiment consisted of
students witnessing substantially cleaned water dripping from their filters. The EEI teacher then directed the conversation to discuss the time, money, and effort required to clean water for a large city like Dallas. The students discussed the fact that water was unavailable for use when it was going through certain steps of the urban water cycle and the impact that could have on water supplies for the entire city. Students tended to report that in order to maintain an adequate amount of water to use, each person should engage in behaviors that help save water. The students gave examples of behaviors such as turning the water off when brushing teeth and taking shorter showers.

In third grade, the students in this study revisited the concepts of water quantity, the hydrologic cycle, the urban water cycles, and were introduced to types of surface waters, specifically wetlands. The students were given a brief introduction to wetlands which included facts about locations of wetlands and biotic features. This lesson was more focused on students actively participating in an experiment. The students were given a tray (to simulate a tract of land), a stopwatch, water droppers, a cup of water, clay, and a piece of carpet (to simulate a wetland). The students' trays were propped on a book and the top of the tray represented the land area and the bottom of the tray represented the Trinity River. The students were instructed on how to “rain” on their “land” (tray) and were then asked to measure the amount of time it took for the “rain” to travel over their “land” and into the Trinity River. Then, the students were asked to formulate a hypothesis as to what would happen if a wetland (carpet) were added to their “land”. The students “rained” on their “land” and reported that a noticeable time difference occurred for the water to reach the Trinity River, or the bottom of their tray. Students and the EEI teacher engaged in a discussion of the roles of a wetland, namely
the ability to slow the flow of water and to clean water. The students then discussed the impacts that wetland removal would have on water supplies and how humans are dependent upon water for survival. Students were then encouraged to discuss ways they could save water at home or at school. Responses included turning the water off when brushing teeth and washing hands, taking short showers, and not letting the water fountain run while talking to a friend in the hallway.

The fourth grade students in this study were once again engaged in a hands-on activity. The lesson began with a review of water quantity, the hydrologic cycle, the urban water cycle, and sources of surface water such as lakes and rivers. The lesson focused on groundwater sources, namely aquifers and their soil properties. The EEI teacher used materials to help students build their very own model of an aquifer, such as cups, clay, sand, rocks, water droppers, and water. Although Dallas mainly uses water from reservoirs, the students learned about other communities that rely on sources of groundwater for consumption and other uses. A specific aquifer mentioned in the lesson is the Ogallala aquifer because it is one of the world's largest and a portion is located in the Texas panhandle. The student's form hypothesis as to how much water each material would hold before run-off or saturation would occur for hardscape (the cup), clay, sand, and rock. Students tested their hypothesis about which material would hold more or less water and discussed the implications for aquifers and areas of land that contained each type of material. Drop by drop, students tested the amount of water each material held until the aquifer was at the point of saturation. At that point, the EEI teacher and students discussed how humans get water out of an aquifer to use for daily activities. The students used the water droppers to create a “well” and extracted water
from their model. The EEI teacher posed questions to the students such as, “What would happen if humans pumped water out of an aquifer faster than it can be recharged by rain?” Students typically responded with comments that people would “run out” of water. Those comments led to a discussion of behaviors students could do to conserve water at school and in their homes. Responses included turning the water off when brushing teeth and washing hands, taking short showers, and not letting the water fountain run while talking to a friend in the hallway.

The final lesson of the K-5 program was provided to the fifth graders in this study. Again, the students revisited concepts such as water quantity, the hydrologic cycle, the urban water cycle, surface and ground water from previous lessons, and were then introduced to the concept of individual behaviors that contribute to water use and conservation. Students revisited where Dallas gets its water and were involved in a hands-on simulation between two different families. One family, the Brewers, engaged in behaviors that increased their use of water. The other family, the Andrews, engaged in water conservation behaviors that decreased their water use. The students were given two buckets, one to represent their own private reservoir and the other to represent where used water goes after it went down the drain, which was the wastewater treatment plant. The students measured the level of water in their bucket prior to the lesson. The EEI teacher read from a series of cards which detailed a behavior the families participated in, such as leaving the water on while brushing their teeth (Brewers) and taking short showers (Andrews). The cards contained similar, yet opposite behaviors, and behaviors that would typically happen in a normal household. Each behavior was associated with an amount of water the students would “use” from
their family’s reservoir. For example, leaving the water on while brushing their teeth resulted in one cup of water being used from the Brewer’s reservoir; taking a short shower resulted in only one-half cup from the Andrew’s reservoir. The students typically got half-way through the lesson before making comments about the behaviors and how one family uses more water than the other. At that stage of the lesson, students in the Brewer family also began to denounce their affiliation and attempted to jump families! The EEI teacher used the natural tendency of students to notice and vocalize a pattern as a bridge to the discussion of behaviors. First, though, the students measured the water level again after the behaviors to measure the amount of water used by each family. Using a chart to visual data, the students determined that the Brewer family used approximately twice the amount of water as the Andrews family. A discussion ensued, which included students describing behaviors they could adapt from the Andrews family in their daily lives, such as taking short showers, not using a hose to clean the sidewalk, only washing full loads of dishes and laundry, turning off the water when brushing teeth or washing hands, and installing high-efficiency (low-flow) devices and toilets. The students also calculated how much water their entire school could save if each person turned off the water when brushing their teeth. Students quickly realized that small changes could lead to large savings!

At the end of each water lesson in Grades K-5, students in this study were asked to make a voluntary commitment to save water. Each student also received one of the following:

- A coloring book full of water conservation tips
- A water conservation card game
• A toothbrush holder/timer

Each item the student received served as a take-home extension of the lesson to prompt a conversation about water and water conservation with the student’s friends and family (see Figure 3).

Figure 3. EEI take-home items and commitment card.

The coloring book was illustrated with images of the DWU mascot, Dew, and gave tips on each page for how the student and his or her family can save water at home. Some tips included taking short showers, not using a hose to clean the sidewalk, only washing full loads of dishes and laundry, turning off the water when brushing teeth or washing hands, fixing leaks, and installing high-efficiency (low-flow) devices and toilets. The water conservation card game was similar to the traditional game of concentration, but included pictures of water saving devices or behaviors. The students would have to match the behaviors to be able to win the game. The toothbrush holder/timer served multiple purposes as it sat conveniently on the bathroom at the student’s home. It would
hold a student’s toothbrush, served as a two-minute timer to get students to brush their teeth for the dentist-recommended time, and it served as a reminder of the EEI lessons and specific water conservation behaviors. The EEI teachers told students that when they were ready to brush their teeth, they had to make sure the water was turned off before they turned the toothbrush timer on. All items served to extend the lessons from the classroom to the home and to encourage discussions between the child and parent.

Purpose of the Study

The focus of this study involves the effects of the EEI in-class, K – 5 water conservation lessons, as provided above, on water use behavior. In a review of the literature, programs attempting to measure behavior change in relation to water conservation are increasing in number. However, after reviewing the literature, only three water conservation education program evaluations were found that met the following criteria (see discussion in Chapter 2):

- Taught water conservation concepts and behaviors
- Targeted students in Grades K-12
- Aimed to measure the effect of water conservation education on behavior

Interestingly, each author mentioned a lack of empirical evidence or actual measurable data (Thompson et al., 2011; Middlestat et al., 2001, Birch & Schwaab, 1983) concerning water usage. The three studies were conducted in Virginia, Jordan, and Texas, respectively. Each study taught specific water concepts in a school setting and measured the dependent variables of knowledge, attitude, and behavior, using methods such as multiple-choice tests, Likert-type scale items, yes or no questions, and self-report surveys or actual water meter readings and is discussed further in Chapter 2.
These studies provided insight as to how education has been and is being used to address water quantity and conservation issues and provided support for the need for further research in this area; research which would be narrower in focus and would utilize empirical data as a measure of behavior change. Thus, the current research has two objectives:

1) Quantitatively measure the impact of a water conservation education program on the water usage of single-family homes in three school zones in Dallas, Texas; and

2) Address a gap in the current literature regarding the quantitative evaluation of the impacts of water conservation education programs on behavior change in the form of water use in single-family homes.

Research Questions

1. Does water use change over the course of 12 months in single-family homes located within three school zones that have received a hands-on and inquiry-based water conservation education program?

2. Does water use change over the course of 12 months in single-family homes located within individual school zones that have received a hands-on and inquiry-based water conservation education program?

3. Does the redemption of vouchers for high-efficiency toilets influence the water use in single-family homes located within three school zones that have received a hands-on and inquiry-based water conservation education program?
Hypotheses

1. \( H_0 \): A statistically significant change in water use will not be evidenced in single-family homes, located in an area that contains three selected school zones that have received hands-on, inquiry-based water conservation education over the course of one calendar year.

\( H_a \): A statistically significant change in water use will be evidenced in single-family homes, located in an area that contains three selected school zones that have received hands-on, inquiry-based water conservation education over the course of one calendar year.

2. \( H_0 \): A statistically significant change in water use will not be evidenced in single-family homes located within individual school zones in the research area over the course of one calendar year.

\( H_a \): A statistically significant change in water use will be evidenced in single-family homes located within individual school zones in the research area over the course of one calendar year.

3. \( H_0 \): High-efficiency toilets do not influence the amount of water used in areas that have received a hands-on, inquiry-based water conservation education program.

\( H_a \): High-efficiency toilets do influence the amount of water used in areas that have received a hands-on, inquiry-based water conservation education program.
CHAPTER 2
LITERATURE REVIEW

Environmental Education

This chapter begins with a brief perspective of the origins of environmental education (EE) because of its implications on water conservation education and behavior change.

EE began to emerge as a distinct field towards the late 1960s, with roots in nature study, outdoor education, and conservation education (Roth, 1992). EE emerged at a time when international concerns about crises and events in the 1960s and 1970s were underway, such as Agent Orange, DDT, TCDD, Love Canal, and Times Beach (Gravanis, 1997; Huggett, 2013; Venables, 2010). The adoption of a globally accepted definition of EE came from a meeting on “Environmental Education in the School Curriculum” held in Nevada, Arizona in 1970, hosted by the International Union for Conservation of Nature and Natural Resources (IUCN) and United Nations Educational, Scientific, and Cultural Organization (UNESCO):

Environmental education is the process of recognizing values and clarifying concepts in order to develop skills and attitudes necessary to understand and appreciate the interrelatedness among man, his culture and his biophysical surroundings. Environmental education also entails practice in decision-making and self-formulating of a code of behavior about issues concerning environmental quality. (IUCN, 1970, p.11)

The creation of an accepted and working definition of EE spurred the creation of new definitions, documents, goals, guidelines, objectives, policy recommendations, programs, and resources at international, national, and local levels (Palmer, 1997). The Belgrade Charter, adopted in 1975, stated that individuals should commit their behavior to global improvement and that reordering of priorities on the national and local scale
was central to the development of a global approach. Goals stated in the charter included improving relationships with nature and people and developing aware and knowledgeable citizens who possess the motivation to act. Several objectives mentioned in the charter are still pervasive in EE today, such as awareness, knowledge, attitude, skills, evaluation ability, and participation (UNESCO, 1975). Two years after The Belgrade Charter, the Tbilisi Declaration added additional goals for efforts within and outside of formal education settings, such as the interdependence of economic, social, and political spheres in rural and urban areas, opportunities for all person to acquire the necessary knowledge, attitudes, skills, values, and commitment to improve the environment, and the creation of new patterns of behavior for individuals and groups towards the environment (UNESCO, 1977).

EE programs, in general, seek to address and impact participants’ knowledge, attitude, and behavior in relation to environmental issues and may vary in scope, duration, and target audience (Stapp, 1969; Ballantyne, Fien, & Packer 2000; Hungerford & Volk, 1990). Programs may last for days, weeks, months, or years and many target children in Grades K-12 (Middlestadt et al., 2001; Dimopoulos, Paraskevloposos, & Pantis, 2008; Kasapoglu & Turan, 2008; Leeming, Porter, Dwyer, Cobern, & Oliver, 1997), while others seek to address the community at large (Martinez-Espinerira, Garcia-Valinas, and Nauges, 2014; Cockerill, 2010; Corral-Verdugo et al., 2003; Simmons & Widmar, 1990). Some areas of the research are focused on measuring and understanding the effects of EE on responsible environmental behavior. Marcinkowski (as cited in Simmons, 1991) argues that the terminal goal of EE is in fact responsible environmental behavior; with the other goals of EE playing a role in insuring
the terminal goal is met. Disinger mentioned (as cited in Zelenzy, 1999) “those concerned about environmental issues generally focus on education as the key to improving environmental behavior” (p. 5).

EE programs deliver content using educational formats, but can also deliver content using communication methods which are considered more informational in nature. Personal and professional training in the field of education has shaped the researcher’s ability to discern between educational and information programs. EE programs using educational teaching methods and modes of content delivery may include:

- Lessons aligned to state and national learning standards
- Hands-on activities / experiments
- Group discussions / interviews / presentations / lecture / writing exercises
- Textbooks / booklets / trade books
- Take-home activities or homework
- Utilizing multiple methods in a single program

(Sutherland and Ham, 1992; Uzzell, 1994; Leemming et al., 1997; Ballantyne, Connell, and Fien, 1998; Legault and Pelletier, 2000; Ballantyne, Fien, and Packer, 2001; Vaughan, et al., 2003; U.S. Department of Agriculture, 1970; D’Agostino et al., 2007; National 4-H Council, 1994; Campbell, 2004; Lindemann-Matthies, 2002; Smith-Sebasto and Semrau, 2004). While searching through the literature on EE programs, it also became evident that some evaluations and papers discussed programs which provided mostly informational methods of communication, such as:

- Newspaper / magazine articles
• Radio/ television commercials / ads / videos
• Smart meters and other feedback – graphs, alerts, or games
• Posters/ pamphlets / brochures / informational packets / flyers / fact sheets
• Annual reports, websites
• Clean-up events / booths at a public events / children’s events

just to name a few (Erickson et al., 2012; Espinosa and Jacobson, 2012; Brozozowski, 2011; Clark and Finley, 2008; Cutts, Saltz, and Elser, 2008; Abrahamse, Steg, Vlek, and Rothengatter, 2007; Agbola, Olurin, and Mabawonku, 1999; Michelsen, McGuckin, and Stumpf, 1999; Wagenet et al., 1999; Walesh, 1999; Nyamwange, 1996; Holl, Daily, and Ehrlich, 1995; Anderson, 1993; Baumann, 1993; Baumann, 1990; Mee, 1990; Nelson, 1990; Griffin, 1989; Larson, Zimmerman, and Scherer, 1982; U.S. Department of Agriculture, 1977). In the review of relevant literature, it was discovered that the majority of those resources cited above came from the field of water resource management rather than EE.

For the purpose of this study, it is important that the difference between education and information be addressed. The difference is stated best by Coyle (2004) in a draft of the National Environmental Education and Training Foundation three-year report, *Understanding Environmental Literacy in America and Making it a Reality*:

What passes for environmental education in America is usually environmental information. One might compare it to the difference between a full-course meal and a quick snack. True education nourishes a deeper understanding and an all-important ability to apply knowledge while information simply makes one aware of a topic and stops there…Those who are often the most anxious for a change in public environmental understanding are prolific information providers. Ironically, they often lack skill as educators. They publish checklists and guidebooks, give public addresses, issue press releases, produce films and obtain media coverage, issue attractive posters and more. But these attempts at
The research in this study focuses on the elementary lessons of an EE program, the EEI. The program is directed by a former classroom and certified teacher and the lessons are taught by certified teachers. It is safe to say that the EEI is grounded in pedagogy and science education methods and provides in-depth knowledge, understanding, and the ability for students to apply their knowledge to particular situations regarding water and water conservation through school-based, hands-on, and inquiry-based lessons. This literature review focused on those water conservation programs and studies which included educational components and not informational campaigns and methods.

Behavior Change in Environmental Education

Hollweg, et al. (2011) stated that “students are interested in applying what they have learned and a growing body of theory and research suggests that active participation may promote other components of environmental literacy and cultivate lifelong environmentally responsible behaviors” (pp. 2-5). Environmental educators have been using behavioral research to inform the creation of campaigns and programs (Hungerford and Volk, 1990; Heimlich and Ardoin, 2008; Leeming and Porter, 1997; Legault and Pelletier, 2000; Ballantyne, Fein, and Packer, 2000). Heimlich and Ardoin (2008) identified and described several models of behavior change that can assist professionals and practitioners, such as the communication/persuasion model, locus of control, integrated model of behavioral prediction, responsible environmental behavior, and social learning. Within the responsible environmental behavior model, Hungerford
and Volk (1990) critiqued the notion that behavior change stemmed from a linear change in knowledge and affect alone. Alternative models were then created to explore the challenge set forth by Hungerford and Volk (1990) and research began to focus on a hierarchy of variables beginning with predispositions of the participant, commitment and ownership, an intention to act, skill set, and self-efficacy. Heimlick and Ardoin (2008) attest that it is in the best interest of the practitioner, program, and participants that human motivation is understood and a level of commitment from the participant is encouraged. Moore and Crompton (as cited in Schultz, 2011) reported that while concern and awareness for environmental issues may be high, substantial changes in actions and behavior have not been realized to date.

Alternatively, more literature shows positive results. Several studies conducted for the purpose of measuring the ability of an educational program in changing behavior included methods such as surveys, scales, or indices (Alp, Ertepinar, Tekkaya, and Yilmax, 2008; Smith-Sebasto, and Fortner, 1994; Leeming et al., 1997) issue investigation (Ramsey, 1993; Ramsey and Hungerford, 1989), questionnaires and self-report measures (Grodzinska-Jurczak, Bartosiewicz, Twardowska, and Ballantyne, 2003; Kruse and Card, 2004), and role modeling and verbal responses (Wagstaff and Wilson, 1998). Results of these studies showed positive effects on behavior change even though various methods of content delivery and data collection were employed, with the majority of methods using self-reported behaviors from participants. Researchers interested in measuring changes in behavior due to education programs are cautioned that oftentimes self-report responses may not portray an accurate reflection of actual behavior change (Martinez-Espineria, Garcia-Valinas, and Nauges,
In relation to water conservation education and measurement of water use, empirical data, rather than self-report data, may be more useful in determining the effects of the program on behavior change (Willis, Stewart, Panuwatwanich, Williams, and Hollingsworth, 2011; Thompson et al., 2011; Clark and Finley, 2008; Clutts, Saltz, and Elser, 2008; Middlestat et al., 2001; Michelsen, McGuckin, and Stumpf, 1999; Berk, Schulman, McKeever, and Freeman, 1993; Dziegielewski, 1990; Birch & Schwaab, 1983; Hamilton, 1985).

Water conservation and resources education does not only pertain to water managers, scientists, and researchers, but is in addition important for the general public (Firth, 1999). Nelson (1993) considers education to be an important connection to public participation and that the education of children allows for information to be shared with parents. Viessman (1990) concurs that water resources education should be implemented in school curricula so that benefits of the education can transfer from students to parents in a “student-parent network” (p. 14). This transfer of information from one party to another has been referred to in the literature as intergenerational transfer.

Intergenerational Transfer

Intergenerational transfer is the transfer of knowledge, attitudes, or behavior changes that can occur from a child to an adult or vice versa (Duvall and Zint, 2007; Uzzell, 1999). The focus on child-to-adult transfer can help EE leaders to indirectly educate the public about current issues concerning the environment by using students
as catalysts for change (Ballantyne et al., 2000). A relatively new concept being studied in EE, intergenerational transfer has been measured in several studies. Duvall and Zint (2007) reviewed seven studies which occurred between 1992 and 2003 and involved K-12 EE programs ranging from 1.5 hours in duration to a 1-year program that incorporated concepts into the school curriculum. Table 1 shows a summary of the articles and educational programs studied.

Table 1

*Summary of Articles on EE Programs Fostering Intergenerational Learning*

<table>
<thead>
<tr>
<th>Reference</th>
<th>Grade</th>
<th>Topic</th>
<th>Teaching Method</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sutherland &amp; Ham (1992)</td>
<td>6</td>
<td>Local watershed</td>
<td>Booklet</td>
<td>3 weeks</td>
</tr>
<tr>
<td>Uzell (1994)</td>
<td>5 - 7</td>
<td>Water pollution</td>
<td>Interview, diary</td>
<td>2 weeks</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Water pollution</td>
<td>Hands-on activity, diary, take-home activities</td>
<td>6 months</td>
</tr>
<tr>
<td>Leeming, Porter, Dwyer, Cobern, &amp; Oliver (1997)</td>
<td>1 - 7</td>
<td>Environmental/ conservation issues</td>
<td>Activities</td>
<td>1 year</td>
</tr>
<tr>
<td>Ballantyne, Connell, &amp; Fein (1998)</td>
<td>5</td>
<td>Endangered flora and fauna</td>
<td>Drama, story, interactive quiz</td>
<td>1.5 hours</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Electricity safety and conservation</td>
<td>Class discussion, hands-on activity, homework</td>
<td>2 months</td>
</tr>
<tr>
<td>Legault &amp; Pelletier (2000)</td>
<td>6</td>
<td>Green School Project</td>
<td>Integration of ecology into the curriculum</td>
<td>1 year</td>
</tr>
<tr>
<td>Ballantyne, Fein, &amp; Packer (2001)</td>
<td>5 , 7</td>
<td>Water and land use</td>
<td>Drama, story, water testing, class discussion, worksheets, field trip</td>
<td>1-5 months</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Local environmental issues</td>
<td>Small group research, presentations, written report</td>
<td>5 months</td>
</tr>
<tr>
<td>Vaughan, Gack, Solorazano, &amp; Ray (2003)</td>
<td>3 , 4</td>
<td>Scarlet Macaw conservation</td>
<td>Class lecture, coloring books, homework</td>
<td>1 month</td>
</tr>
</tbody>
</table>

Overall findings from the review suggested that “K-12 EE programs have only a modest potential to influence parental knowledge, attitudes, and behavior” (Duvall and Zint, 2007, p.20). The review provided a list of suggested factors that may facilitate intergenerational transfer, many of which involve an increase in community within and out of the school. Duvall and Zint (2007) reported limitations of all the studies, which included:

- Short duration, with only two of the seven studies having programs lasting longer than 6 months
- Teacher implementation and teaching methods were not reported, which makes it unclear whether the methods indicated were actually used
- Follow up tests and studies were not conducted except in one of the studies, making it difficult to measure the resilience of intergenerational transfer; some information was shown to transfer beyond the student and parent and extended into the community
- The majority of programs, 7 out of 10, did not include a homework or take-home component which could have possibly encouraged family discussion (p. 20)

Factors that may contribute to EE program development and facilitate intergenerational learning were reported and include (Duvall and Zint, 2007, pp. 21-22):

- Projects that allow children to share up-to-date knowledge with their parents and boost students’ feeling of status within the family
- Projects that encourage community within the school environment and that encourage schools to engage with the larger community
• Parental involvement in student activities was critical and can take the form of homework, discussion, take-home projects, or research activities

• Community involvement from members outside of the school should be encouraged to engage in events and projects within the school community

• Hands-on activities not only capture children’s’ interest, but also engage adults in interacting with the child; children are more likely to share hands-on activities with their family

• Programs that provide adequate time for in-depth coverage of content and discussion and should include information about how to perform specific behaviors relative to the EE concepts

• A focus on local issues to promote a sense of ownership, exploration, and relevance for children and adults

• Enthusiastic teachers committed to learning and the program had greater chances in generating enthusiasm in their students

Table 2 shows how the EEI water conservation education program addresses the limitations and factors that attempt to facilitate intergenerational transfer described by Duvall and Zint (2007). The remarks about EEI in Table 2 are based on the researcher’s knowledge of and participation as a certified teacher in the EEI program since 2009.
### Table 2

*Features of the EEI Water Conservation Education Program*

<table>
<thead>
<tr>
<th>Duvall and Zint (2007)</th>
<th>City of Dallas EEI Water Conservation Education Program</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Limitations:</strong></td>
<td><strong>How EEI addresses limitations:</strong></td>
</tr>
<tr>
<td>Short duration</td>
<td>EEI program implemented since 2006; return to schools year after year; conduct professional development workshops for teachers</td>
</tr>
<tr>
<td>Implementation and teaching methods not reported</td>
<td>Teachers are cross-trained; lessons have specific teaching methods for each grade level; teachers are evaluated by co-worker before allowed to teach on his or her own</td>
</tr>
<tr>
<td>Follow-up tests and studies not conducted</td>
<td>Two studies conducted (2011 &amp; 2012) by EEI teachers and director on program; the studies have informed the current study</td>
</tr>
<tr>
<td>Did not include homework or take-home component</td>
<td>Each lesson includes a take-home component such as a coloring book, water conservation card game, or toothbrush holder/timer; K, 1st, and 4th lessons include take-home item from the lesson (six-ounce cup for brushing teeth, water cycle bracelet, and aquifer)</td>
</tr>
<tr>
<td><strong>Factors that may contribute to intergenerational transfer:</strong></td>
<td><strong>How EEI incorporates factors that may contribute to intergenerational transfer:</strong></td>
</tr>
<tr>
<td>Allows children to share up-to-date knowledge with their parents</td>
<td>Information in lessons update to reflect current knowledge of concepts and policies in Dallas; TEKS and STAAR-alignment updated for most recent standards</td>
</tr>
<tr>
<td>Encourages community within the school environment and community at large</td>
<td>Entire grade-levels are taught the same lesson on the same day; students in all schools have opportunity to attend community events in Dallas</td>
</tr>
<tr>
<td>Community members from outside of the school included in events and projects</td>
<td>UNT students represent DWU to teach lessons; DWU staff members visit school and evaluate teachers; DWU staff members attend professional development workshops</td>
</tr>
<tr>
<td>Adequate time for in-depth coverage of content and discussion about how to perform specific behaviors</td>
<td>45-minute lessons given to one class (average class size of 20 students) at a time and include conversations about specific water conservation behaviors students can use at school and at home</td>
</tr>
<tr>
<td>Focus on local issues</td>
<td>Lessons based on natural water resources, treatment processes, ordinances, and population factors specific to Dallas, Texas</td>
</tr>
<tr>
<td>Enthusiastic teachers</td>
<td>Teachers are passionate about science and enthusiastic about water conservation</td>
</tr>
</tbody>
</table>

Studies evaluating intergenerational transfer are important for the effective implementation of water conservation education programs as well. Adults are usually the primary consumers of water in and outside of the home, but children may foster a conservation ethic in the home and remind adults to make an investment in their future and their child’s future (Berk et al., 1993). Individuals with a future-orientation may engage in more water conservation actions, so educational opportunities should engage participants and students in thinking about the future (Corral-Verdugo, Fraijo-Sing, & Pinheiro, 2006; Thompson & Stoutemyer, 1991). By targeting children in EE programs concerning water issues it is possible to impact adults’ knowledge, attitudes, and behaviors about water and water conservation (Ballantyne et al., 2000). By addressing local water quantity issues with a sense of urgency that directly affect a child’s life, family, or town it is possible that children will be more likely to share their knowledge with adults, thus increasing intergenerational transfer (Sutherland & Ham, 1992). Based on the limitations and factors which may contribute to intergenerational transfer outlined by Duvall and Zint (2007), it appears that the EEI program may be successful in addressing limitations and employing features that may contribute to intergenerational transfer (see Table 2).

Water Conservation Education Program Evaluation

As was mentioned in chapter 1, few evaluations of water conservation programs exist (Cutts, Saltz, and Elser, 2008; Clark and Finley, 2008; Michelsen, McGuckin, and Stumpf, 1999; Howard and McGregor, 2000). Evaluations of rebate/water-saving device programs tend to report that while programs may not be cost-effective (Woltemade and Fuellhart, 2012) and studies require large sample sizes (Tsai, Cohen, and Vogel, 2011),
installation of low flow devices may result in significant savings (Geller, Erickson, and Buttram, 1983). Roccaro, Falciglia, and Vagliassindi (2011) asserted that because structural devices may result in significant water savings, it is difficult to measure effects from educational programs. It is important to know that what Rocacaro, Falciglia, and Vagliassindi (2011) refer to as education is actually information in the form of brochures, posters, and questionnaires. Alternatively, the following description of studies considers evaluation of the effect of K-12 educational programs on behavior change.

The keywords “water conservation education” were used to search sources such as Google Scholar™, EBSCOhost®, ERIC, and Web of Science™ and returned articles from the 1980s to the present in the fields of water resource management and environmental education. Within water resource management, the majority of articles tended to pertain to either information programs or education programs (see discussion about education versus information towards the beginning of this chapter). Few studies which aimed to measure the effect of water conservation on behavior were found. Of those that were found, very few (three) pertained to the effect of K-12 education on behavior.

Table 3 shows the number of studies relevant to water conservation education that were discovered in the literature.
Table 3

*Number and Description of Articles: “Water Conservation Education”*

<table>
<thead>
<tr>
<th>Description of Topics Addressed in Articles</th>
<th>Number of Related Articles Found</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Resource Management</td>
<td>25</td>
</tr>
<tr>
<td>Water Resource Management: Information</td>
<td>19</td>
</tr>
<tr>
<td>Water Resource Management: Education</td>
<td>10</td>
</tr>
<tr>
<td>Water Conservation Studies: Effect on Behavior</td>
<td>9</td>
</tr>
<tr>
<td>K-12 Water Conservation Education Program: Effect on Behavior</td>
<td>3</td>
</tr>
</tbody>
</table>

A screenshot of the results of a search for “water conservation education” articles in the database *ERIC* can be seen in Figure 4. A total of sixteen results surfaced, which is a testament to the lack of abundance of studies on water conservation education programs currently available in the literature. Of the sixteen, the three K-12 water conservation education program studies that sought to measure an effect on behavior are described in detail below and are indicated by a red arrow.
Figure 4. Screenshot of search for "water conservation education" articles.
Of the 66 articles, three studies, conducted in Virginia, Jordan, and Texas were found in the EE literature which met the following criteria:

- Taught water conservation concepts and behaviors
- Targeted students in Grades K-12
- Aimed to measure the effect of water conservation on behavior and thus were probative for this study.

In the first of the three studies, Birch and Schwaab (1983) tested the assumption that EE programs in schools are successful in encouraging water conservation by teaching a unit to 843 seventh-grade students in Virginia. The unit lasted one week and consisted of a slideshow with water conservation techniques and behaviors, living organisms and their dependence on water, models and demonstrations, an informational booklet, and a video depicting individuals engaging in actions that either save or waste water. Students were randomly assigned to one of four groups that received a post-test after one week. Group 1 received a pre-test, instructional unit, and post-test. Group 2 only received a pre-test and post-test. Group 3 only received the instructional unit and a post-test. Group 4 only received a post-test. The dependent variable of knowledge was measured using a multiple-choice test and attitude was tested by measuring scores on a Likert-style tool, both related to water and water conservation. Results of the study indicated that there were significant increases in the knowledge and attitude scores in Group 1 and 3. For students that received the instructional unit, results also revealed a strong relationship between knowledge and attitude scores. It is relevant to recognize that knowledge and attitude scores change after teaching a unit on water conservation, yet the limiting factor of this study was the
lack of empirical data which could demonstrate an actual change in the student’s behavior based on this new knowledge and attitude. (Birch & Schwaab, 1983). Future research recommendations included monitoring water usage in a fixed situation, such as water meter records, to inform future EE program planners and utility managers who determine the cost-effectiveness of such programs.

The second study, conducted by Middlestat et al. (2001) measured the impact of an educational program implemented through the Jordan Water Conservation Education Project in high school eco-clubs located in Central Jordan. The experimental group consisted of 424 students and the control group contained 247 students, with each group having similar demographic and academic characteristics. For six weeks, teachers implemented the curriculum, which contained five units: background information about the water cycle, sources of water, ground water vs. surface water, household water conservation, and irrigation. Each unit lasted one eco-club session, but the duration of the session was not reported in the article. The program, which was delivered over a five month period, involved relevant discussions, questions, activities, a pre- and post-test, and a self-report water behavior survey. Specific water conservation behaviors for inside and outside of the home were advocated for both students and parents. The dependent variables of knowledge, attitudes and beliefs, social behaviors, and conservation behaviors in the home were tested. Self-report results indicated that participation in the unit had a strong impact on students’ knowledge and behavior (Middlestat et al., 2001). Again, a limitation of the study was that an objective, quantitative analysis of actual behaviors did not occur to verify the results of the self-reported behaviors.
In the third study, in Texas, Thompson et al. (2011) implemented a research-informed water conservation EE program in public schools located in the City of Dallas, beginning in 2006. The team of researchers conducted a citizen survey of residents in the Upper Trinity River Watershed prior to the implementation of the program. The researchers analyzed the survey data, formed a team of local teachers and scientists, and developed a water conservation curriculum taught by certified elementary and middle school teachers seeking graduate degrees in environmental science. Based on results from the survey, a spiraling curriculum (Bruner, 1960) was created to contain locally relevant, hands-on, age appropriate lessons for students in Grades K-5. Beginning in Kindergarten and culminating in fifth grade, concepts such as water quantity, the water cycle, the urban water cycle, surface and ground water sources, and watershed dynamics built upon each other. To determine whether or not the lessons aligned with state standards and school needs, the teachers were asked to complete an evaluation, rating both the presenter and the content of the lessons. Students were also asked to make a voluntary commitment to save water in their home by performing an action, such as turning off the water when they brushed their teeth. Results of the first four years, 2006-2010, demonstrated that the program may be effective in changing student behavior, based on self-reported behaviors. During that time, the program served 17,000 students and visited approximately 800 classrooms. Yet again, the limitation of this initial program was a lack of empirical, quantitative data which could measure an actual behavior change.

The preceding studies are examples of EE programs that have potentially demonstrated success in impacting students’ knowledge, attitudes, and behavior
concerning water conservation and water quantity. The studies also reveal limitations of the current perspectives and practices in environmental education, namely the length of the studies and a lack of actual quantitative data measuring behavior changes. EE program evaluations and research need to continue so that a true picture of water conservation behaviors can be seen, but they must contain evidence of actual, measurable data (Thompson et al., 2011; Clark and Finley, 2008; Clutts, Saltz, and Elser, 2008; Middlestat et al., 2001; Michelsen, McGuckin, and Stumpf, 1999; Dziegielewski, 1990; Birch & Schwaab, 1983; Hamilton, 1985). In addition, Cutts et al. (2008) also suggested using GIS to demonstrate and highlight differences in campaign efforts and effects at the neighborhood level. This research employs the use of GIS and a quantitative analysis using empirical data in the form of water meter records for single-family homes in three school zones in an attempt to address the current gap in the literature.
CHAPTER 3

METHODOLOGY

The purpose of this study was to determine whether a water conservation education program taught in public schools had an effect on water usage in single family homes located within the respective school zones. The researcher also sought to identify and control for additional factors and threats to validity that could confound water usage, such as precipitation, temperature, irrigation ordinance, marketing, price of water, median household income, number of housing units, population, geographic location, and use of high-efficiency toilets. A quasi-experimental design was used in the study, which included a pre-observation of water usage, treatment, and post-observation of water usage for one group, which contained single family homes in three school zones in Dallas, Texas. Monthly water usage, in gallons, was provided by the City of Dallas Water Conservation Division (DWU) for each single family home in the research area and did not include any personally identifying information.

This chapter presents the methods used in the study. Additionally, other sections describe previous studies that led to the current research design, research hypotheses, zip code and housing data, school zone demographics, information about the conservation education lessons, data collection, and analysis of the data.

Previous Studies and Contribution to Current Research Design

In the summer of 2011, average monthly water use data from 2008-2010 was analyzed by Thompson (unpublished raw data) for single-family homes in three separate areas in Dallas, Texas. The study design contained two treatment groups and one control group. One treatment group contained schools that had received hands-on,
water conservation lessons from the City of Dallas Environmental Education Initiative (EEI) for some of the classrooms. The second treatment group received both targeted marketing by DWU and water conservation lessons from EEI. The control group received neither marketing nor a mixture of marketing and education, which served as the independent variables in the study (see Figure 5).

Figure 5. Map of 2011 research area.

The results of a three-way ANOVA (alpha level set to 0.05) indicated that the mean monthly water use all groups in 2009 was statistically significantly lower than in 2008 ($p = 0.03$) and 2010 ($p = 0.04$), yet the control group had statistically significantly higher mean monthly water use than either of the treatment groups ($p<0.001$) [Thompson, unpublished raw data]. Because the control zip code experienced a slight decrease in water use, though not statistically significant in comparison to the treatment
groups, a replication study (see Figure 6) was planned for the following summer, which would take into account additional factors that could affect water use, such as precipitation, temperature, irrigation ordinance, marketing, price of water, median household income, number of housing units, population, and geographic location.

Figure 6. Map of 2012 research area.

In the summer of 2012 water use was measured between two areas in Dallas, Texas with similar geographic locations, numbers of housing units, median household income levels, and population. Precipitation and temperature data were reported for the areas as a whole. Both areas had an average precipitation of 36.62 – 37.14 inches of rain per year (National Oceanic and Atmospheric Administration, 2012a) and a mean temperature of 80 – 85 degrees Fahrenheit (National Oceanic and Atmospheric
Since the temperature and precipitation did not differ across the two areas, these factors were considered constants in the study.

Effective April 23, 2012, the City of Dallas enacted a maximum twice-a-week watering ordinance from April 1 to October 1 as part of an extension to the city’s Stage 1 drought contingency plan. The ordinance affected citizens living throughout the entire City of Dallas (DWU, 2014). The City of Dallas uses a tier structure for the price of water for residential use, with four tiers and prices given per 1,000 gallons used. Tier I consists of water use up to 4,000 gallons and the price per 1,000 gallons is $1.80. Tier II consists of water use between 4,001 and 10,000 gallons with the price of water per 1,000 gallons being $3.77. Tier III consists of water use between 10,001 and 15,000 gallons with the price of water per 1,000 gallons being $5.20. Finally, Tier IV consists of water use above 15,001 gallons and the price per 1,000 gallons was $7.09 (A. M. Wilson, personal communication, December 12, 2013). The tier structure was consistent for all residential customers throughout the entire City of Dallas. Any marketing strategies in place in Dallas were used throughout the city and were not targeted to a particular area (e.g., billboards, bill inserts, bus signs, and a campaign called “The Lawn Whisperer”). Having taken into account all known variables previously stated and including the additional potential variables, of the twice-a-week irrigation ordinance, tiered price of water, and marketing strategies, which were all consistent throughout the entire city, an identified difference left between the two groups was the number of students that did or did not received education in the form of water conservation lessons from EEI since 2006.
The results included the average monthly water usage data for single-family homes for a period of fourteen months, from January 2011 – April 2012. Water use data was provided by the DWU and did not contain any personally identifiable information. In Research Area 1 (see Figure 6), only 186 students had received the lessons since the inception of the EEI program in 2006 and thus this area served as the control. In Research Area 2 a total of 4,190 students had received the lessons since 2006 and so served as the intervention. The independent variable was the number of students taught in the school zones in each research area and the dependent variable was water usage. Thompson (2012) reported that the average monthly water usage in Research Area 1 was statistically significantly higher, by 89 gallons, than the average monthly water usage in Research Area 2 (\(t\)-test, \(p<0.001\)) [unpublished raw data].

The two previous studies appear to suggest that the EEI program has a measurable effect on the water conservation behavior of student participants. But now the question becomes, how long does it take to see change? In other words, is it possible to see water savings in an area with previously high water use, and almost negligible conservation education, over the course of one calendar year?

Research Design

The researcher measured the effect of a water conservation education program on water use in single-family homes in three school zones located primarily in the zip code 75224 in Dallas, Texas (see Figure 7) over a 12 month period. The study includes one group and is a quasi-experimental design which uses a baseline or pre-observation, a treatment, and an observation during the period over which the educational treatment occurred. The schools targeted in the study were chosen because the previously
mentioned studies had shown that the area in which they were located had statistically significantly higher average monthly water use than areas that had received water conservation education lessons, and because the schools had not previously received the EEI water conservation education. For this study, the researcher analyzed the average monthly water usage over a period of one school year for single-family homes in the targeted school zones before, during, and after the educational intervention.

![Figure 7. School zones and schools that received EEI lessons in zip code 75224.](image)

Zip Code Demographics and Housing Data

Each school zone was primarily located in zip code 75224. One value was reported by the American Fact Finder of the United States Census Bureau (2010) for
median household income, number of housing units, and population for this zip code. According to the 2010 census, the median household income of this zip code was $32,834; the total number of housing units was 11,184, the number of occupied housing units was 10,221, and the population was 34,034. Since one value for the median household income, number of occupied and total housing units, and population was reported over the entire zip code, those factors were considered constants in the study. In addition, the National Oceanic and Atmospheric Administration (2012a,b) reported the precipitation for the zip code as 36.62 – 37.14 inches for the year and the average annual temperature as 80 – 85 degrees Fahrenheit. Again, since this was one zip code the amount of rain and average temperature did not differ across the zip code, which had a geographic area of less than five square miles, therefore those factors were also considered constants. Finally, policy influences such as the twice-a-week irrigation ordinance enacted in April 2012, the tiered price of water, and city-wide marketing strategies were also the same for every member of this zip code and the City of Dallas, so they, too, served as constants in the study.

Having taken the following factors into account:

- Precipitation
- Temperature
- Irrigation ordinance
- Marketing
- Price of water
- Median household income
- Number of housing units
• Population
• Geographic location
• Use of high-efficiency toilets

The researcher was left with the independent variable of the water conservation education lessons to contrast with the dependent variable of water use in single-family homes.

According to the United States Census Bureau’s American Fact Finder (2010), the zip code 75224 had a demographic that consisted of multiple races, with 60.2% of all races identifying as Hispanic or Latino and 39.8% of all races identifying as Not Hispanic or Latino. Within the demographic that identified as Not Hispanic of Latino, 41.9% identified as White and 27.9% identified as Black or African American.

Of the 11,184 housing units in the zip code 75224, the American Fact Finder (2010) reported that 5.8% of the structures were built in or prior to the year 1939, 72.3% were built between the years 1940 – 1979, and 21.9% were built between the years 1980 – 2009. The data reported that zero houses were built after 2010.

Of the total number of occupied housing units, Table 4 shows a breakdown of the number of housing units within a structure. This study focused on analyzing the water use of single-family units, referred to as “1-unit, detached” in Table 4, within the school zones which received water conservation education lessons from EEI.

The United States Census Bureau (2010) reported the household sizes and presence of children for zip code 75224. The percent of households with children was reported to be 45.4 % and the percent of households with no children was 54.6%. Household sizes with one person were reported as 23.8%, two persons were 24.6%
and 3 or more persons were 51.7%. Please note that these values which were reported equate to a sum of 100.1%.

Table 4

*Number and Type of Housing Units in Zip Code 75224*

<table>
<thead>
<tr>
<th>Number of Units in a Structure</th>
<th>Number of Units in Zip Code 75224</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-unit, detached</td>
<td>7,187</td>
</tr>
<tr>
<td>1-unit, attached</td>
<td>172</td>
</tr>
<tr>
<td>2 units</td>
<td>207</td>
</tr>
<tr>
<td>3 or 4 units</td>
<td>575</td>
</tr>
<tr>
<td>5 to 9 units</td>
<td>963</td>
</tr>
<tr>
<td>10 to 19 units</td>
<td>680</td>
</tr>
<tr>
<td>20 or more units</td>
<td>1,374</td>
</tr>
</tbody>
</table>

*Source:* U.S. Census Bureau, 2008-2012 American Community Survey 5-Year Estimates

School Demographics

According to the Dallas ISD Office of Institutional Research (2013), demographics of the student population for the 2012 – 2013 school year showed a majority percentage of Hispanic race/ethnicity for three of the four elementary schools in the research area. Carpenter Elementary was the only school in the study that reported that 53.2% of the students were classified as African American, 0.3% White, and 46.5% Hispanic. In addition, student enrollment reflected that 98.0% of the school was considered to be economically disadvantaged, 32.7% was limited English proficient, and 60% was at-risk. In contrast, Henderson Elementary reported 2.0% of the students were classified as African American, 0.4% White, 0.4% other, and 97.1% Hispanic. Student enrollment reflected that 96% of the school was considered to be economically
disadvantaged, 60.8% was limited English proficient, and 77.8% was at-risk. Jordan
Elementary reported 15.9% of the students were classified as African American, 0.5%
White, and 83.6% Hispanic. Student enrollment reflected that 96.8% of the school was
considered to economically disadvantaged, 65.1% was limited English proficient, and
76.9% was at-risk. And similarly, Russell Elementary reported 12.3% of the students
were classified as African American, 0.6% White, 0.5% other, and 86.4% Hispanic.
Student enrollment reflected that 98.2% of the school was considered to be
economically disadvantaged, 65.3% was limited English proficient, and 77.8% was
considered at-risk.

Water Conservation Education Lessons

In the study, all four schools received water conservation education lessons for
each classroom in each grade level (see Table 5). The four schools which received
lessons were John W. Carpenter Elementary School, Margaret B. Henderson
Elementary School, Barbara Jordan Elementary School, and Clinton P. Russell
Elementary School in DISD.

Working with a counselor at each school, three teachers from the City of Dallas
Environmental Education Initiative taught lessons in each classroom at each
intervention school. All of the teaching occurred from September 14, 2012 – October 31,
2012 and each of the three teachers taught various grade levels at each school (see
Table 6).
Table 5

*Teaching Schedule during Intervention Year*

<table>
<thead>
<tr>
<th>Date</th>
<th>School</th>
<th>Grade</th>
<th>Teacher</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/14/2012</td>
<td>Clinton P. Russell</td>
<td>First Grade</td>
<td>Christina</td>
</tr>
<tr>
<td>9/24/2012</td>
<td>Clinton P. Russell</td>
<td>Kinder</td>
<td>Shane</td>
</tr>
<tr>
<td>9/25/2012</td>
<td>Clinton P. Russell</td>
<td>Pre-K</td>
<td>Christina</td>
</tr>
<tr>
<td>9/26/2012</td>
<td>Clinton P. Russell</td>
<td>Fourth Grade</td>
<td>Shane</td>
</tr>
<tr>
<td>9/26/2012</td>
<td>Clinton P. Russell</td>
<td>Second Grade</td>
<td>Alice</td>
</tr>
<tr>
<td>9/26/2012</td>
<td>Clinton P. Russell</td>
<td>Third Grade</td>
<td>Shane</td>
</tr>
<tr>
<td>9/28/2012</td>
<td>Clinton P. Russell</td>
<td>Fifth Grade</td>
<td>Alice</td>
</tr>
<tr>
<td>10/01/2012</td>
<td>Margaret B. Henderson</td>
<td>Second Grade</td>
<td>Alice</td>
</tr>
<tr>
<td>10/02/2012</td>
<td>Margaret B. Henderson</td>
<td>Third Grade</td>
<td>Christina</td>
</tr>
<tr>
<td>10/03/2012</td>
<td>Margaret B. Henderson</td>
<td>Fourth Grade</td>
<td>Shane</td>
</tr>
<tr>
<td>10/04/2012</td>
<td>Margaret B. Henderson</td>
<td>Fifth Grade</td>
<td>Shane</td>
</tr>
<tr>
<td>10/09/2012</td>
<td>Margaret B. Henderson</td>
<td>First Grade</td>
<td>Christina</td>
</tr>
<tr>
<td>10/09/2012</td>
<td>Margaret B. Henderson</td>
<td>Kinder</td>
<td>Christina</td>
</tr>
<tr>
<td>10/15/2012</td>
<td>John W. Carpenter</td>
<td>Pre-K and Kinder</td>
<td>Alice</td>
</tr>
<tr>
<td>10/16/2012</td>
<td>John W. Carpenter</td>
<td>First Grade</td>
<td>Christina</td>
</tr>
<tr>
<td>10/16/2012</td>
<td>John W. Carpenter</td>
<td>Second Grade</td>
<td>Christina</td>
</tr>
<tr>
<td>10/17/2012</td>
<td>John W. Carpenter</td>
<td>Third Grade</td>
<td>Shane</td>
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<tr>
<td>10/17/2012</td>
<td>John W. Carpenter</td>
<td>Fourth Grade</td>
<td>Shane</td>
</tr>
<tr>
<td>10/18/2012</td>
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<td>Fifth Grade</td>
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<td>10/18/2012</td>
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</tr>
<tr>
<td>10/22/2012</td>
<td>Barbara Jordan</td>
<td>Fifth Grade</td>
<td>Alice</td>
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<td>Barbara Jordan</td>
<td>Fourth Grade</td>
<td>Christina</td>
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<td>10/24/2012</td>
<td>Barbara Jordan</td>
<td>Third Grade</td>
<td>Shane</td>
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<td>10/25/2012</td>
<td>Barbara Jordan</td>
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<td>Shane</td>
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<td>Alice</td>
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<td>Kinder</td>
<td>Christina</td>
</tr>
<tr>
<td>10/31/2012</td>
<td>Barbara Jordan</td>
<td>Pre-K</td>
<td>Shane</td>
</tr>
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</table>
Table 6

Teaching Calendar during Intervention Year

<table>
<thead>
<tr>
<th>SEPTEMBER 2012</th>
<th>SUNDAY</th>
<th>MONDAY</th>
<th>TUESDAY</th>
<th>WEDNESDAY</th>
<th>THURSDAY</th>
<th>FRIDAY</th>
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<td>9</td>
<td>10</td>
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<td>14</td>
<td>RUSSELL</td>
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<td>16</td>
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<td>24 RUSSELL</td>
<td>25 RUSSELL</td>
<td>26 RUSSELL</td>
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<td>28 RUSSELL</td>
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<td></td>
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<tr>
<td>Shane Kinder</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Christina &amp; Shane Pre-K &amp; 4th</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>14 RUSSELL</td>
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<th>THURSDAY</th>
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<td>Shane 4th</td>
<td>Shane 5th</td>
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</tbody>
</table>

58
All three EEI teachers were cross-trained to teach the lessons in a similar manner. All students who were present in each classroom at each school received a hands-on, inquiry-based water conservation lesson, which is part of the K-5 spiral curriculum (Bruner, 1960), that lasted approximately 45 minutes and included facts about water, water sources specific to Dallas, Texas, an experiment or activity, and specific conservation behaviors the students could begin to implement at home or at school, such as turning the water off when they wash their hands and brush their teeth. Each student had the ability to sign a water promise card, which was an indication of their commitment to turn the water off each time they brushed their teeth. Heimlich and Ardoin (2008) discussed how educational efforts which included a commitment component tend to predict an increase in the likelihood of action. Each student also received one of the following:

- A coloring book full of water conservation tips
- A water conservation card game
- A toothbrush holder and timer

Each take-home item served as a conversation-starter for students and their family, and as an at-home reminder of the lesson and specific water conservation behaviors taught by the EEI teachers (see discussion in Chapter 1).

Data Collection

All demographic data for the zip code was collected from the United States Census Bureau American Fact Finder (2010) and demographic data for each school profile was collected from the DISD Office of Institutional Research’s (2013) Data Packet for 2013 – 2014 Planning, made publicly available through the DISD webpage.
Precipitation and temperature data were collected from the National Oceanic and Atmospheric Administration (2012) in the form of shapefiles and image files. The Environmental Systems Research Institute’s (ESRI) (1998) definition of a shapefile states that it “stores nontopological geometry and attribute information for the spatial features in a data set. The geometry for a feature is stored as a shape comprising a set of vector coordinates” (p. 1). A shapefile can contain shapes in the form of points, lines, and polygons (ESRI, 1998). Shapefiles are commonly used in Geographic Information System (GIS), which is a management system which combines a database with a digital mapping component for spatial analysis, and which has applications for use in many fields, including water resources (Lanfear, 1992). Shapefiles containing zip code boundaries, Texas roads and streets, county boundaries, and city boundaries were provided to the researcher during a graduate course entitled GIS for Applied Sciences in the spring of 2013 by Dr. Bruce Hunter at the University of North Texas, but some of the files are available as public information from the City of Dallas GIS Services Department (C. Gardner, personal communication, July 2, 2013). The DISD Demographic Studies Department provided the school district boundaries, school attendance zone boundaries, and school locations in the form of shapefiles (V. Lara, personal communication, June 3, 2013). The original DISD shapefiles contained information for all schools located within the district and the researcher isolated the school zones of interest to plot on a map of the research area (see Figure 7).

All water usage data and toilet voucher data was provided by DWU in July 2013 and February 2014 in an electronic spreadsheet and did include street addresses, but did not include any personally identifiable information. The water use spreadsheet
contained all water data for single-family homes located in all zip codes in the City of Dallas. The original document contained over 236,125 records and the researcher isolated the records of interest for the research area. This was accomplished by sorting and filtering the original data set to include only single-family homes in the zip code of interest (75224), which totaled 104,275 records. Once the records were located for zip code 75224, the addresses were imported and geocoded using ArcGIS® software and ArcMap™ 10.1, allowing them to be plotted on a map. It was at this time that further filtering, sorting, and selection with ArcMap™ 10.1 was used to isolate the single-family homes located within each school zone. The number of single family homes located within all school zones pre intervention was 3,934 and post intervention was 3,943. A total of nine additional homes became occupied from pre to post intervention. Mean monthly water use, in gallons, for single-family homes in each school zone were collected in the research area pre intervention, from May 2011 – April 2012 and post intervention, from May 2012 – April 2013. A total of twelve months of data was reported pre and post intervention for each single-family home, totaling 47,208 data points and 47,316 data points, respectively.

Data Analysis

Using ArcGIS® software and ArcMap™ version 10.1, the research schools, school zones, and zip codes were plotted to create a map of the research area. Single-family home and toilet data, including street addresses were imported in ArcMap™ 10.1, geocoded, and populated on the map as individual data points to determine which homes did or did not lie within the targeted school zones. Only single-family homes that had at least three-fourths of a year of monthly water usage values and that were
contained within the three school zones were analyzed in the study. A more detailed explanation of this process is described in Chapter 4.

In addition, addresses of homes that redeemed a voucher for a high-efficiency toilet in the targeted school zones during the year that educational lessons were plotted with ArcMap™ 10.1 and were removed from the data analysis, addressing the second research question. Any high-efficiency toilets that were redeemed in the targeted school zones prior to May 2012 were included in the analysis because they were included in the baseline water usage that occurred prior to the educational intervention. Since the toilet data was removed from the analysis, the third hypothesis that toilets did not influence the amount of water used in the areas that have received the hands-on, inquiry-based water conservation education program was not rejected. Once the map was created and the homes plotted, Systat Software Inc. software SigmaPlot™ 12.3 was used to analyze the water usage data for the research area and for each school zone. This procedure allowed for the determination of whether or not a statistically significant change in water usage occurred in single-family homes located within the entire area and within the individual school zones that had received a hands-on and inquiry-based water conservation education program.

Summary

This chapter outlined the methodology of the study. Previous studies that contributed to the current research design, research design, zip code demographics and housing data, school demographics, water conservation education lessons, data collection, and data analysis were discussed. Chapter 4 presents the results of the study.
CHAPTER 4

RESULTS

The researcher attempted to measure the effect of a water conservation education program on water use in single-family homes in three school zones located primarily in the zip code 75224 in Dallas, Texas within a 12 month period. The study incorporated a baseline or pre-observation, a treatment, and an observation during the period over which the educational treatment occurred. The schools targeted in the study were chosen because the previously mentioned studies in Chapter 3 had shown that the area in which they were located had statistically significantly higher average monthly water use than areas that had received water conservation education lessons and because the schools had not previously received the EEI water conservation education lessons. The researcher also identified and controlled for additional factors and threats to validity that may confound water usage, such as:

- Precipitation
- Temperature
- Irrigation ordinance
- Marketing
- Price of water
- Median household income
- Number of housing units
- Population
- Geographic location
- Use of high-efficiency toilets
According to the Energy Policy Act of 1992, beginning January 1, 1994 the maximum water use allowed for gravity tank-type toilets, which are primarily used in residential settings, was 1.6 gallons per flush. DWU operates a program which provides water customers a chance to receive a voucher for up to two high-efficiency toilets, if their current toilets were installed prior to 1994. The data for the homes which received vouchers for new toilets was provided by DWU and included addresses, voucher dates, and redemption dates, but did not include names or account numbers. The data reported by the Water Conservation Division did not include data about whether or not toilets were installed after redemption. The homes which showed a date of redemption for a toilet were included in the analysis of water usage and the homes which did not show a date of redemption were not included in the analysis. Having taken all factors into account, the researcher was left with the independent variable of the water conservation education lessons to contrast with the dependent variable of water usage in single-family homes.

Study Participants

Four schools received water conservation education lessons for each classroom in each grade level. The four schools were John W. Carpenter Elementary School, Margaret B. Henderson Elementary School, Barbara Jordan Elementary School, and Clinton P. Russell Elementary School in DISD.

All lessons were taught in the classrooms at each school from September 14, 2012 through October 31, 2012 by one of three teachers from EEI. A total of 2,122 students in 104 classes received a hands-on, inquiry-based water conservation lesson that lasted approximately 45 minutes and included facts about water, water sources
specific to Dallas, Texas, an experiment or activity, and specific conservation behaviors the students could begin to implement at home or at school, such as turning the water off when they wash their hands and brush their teeth (see Table 7). Each student was provided the opportunity to sign a water promise card, which was an indication of their commitment to turn the water off each time they brushed their teeth. Each student also received one of the following:

- A coloring book full of water conservation tips
- A water conservation card game
- A toothbrush holder/timer

Each item the student received served as a take-home extension of the lesson to prompt a conversation about water and water conservation with the student’s friends and family (see Figure 3). As mentioned in Chapter 1, all items served to extend the lessons from the classroom to the home and were provided because research on intergenerational transfer suggests that the inclusion of a take-home component in an EE program may increase discussions and information transfer between the child and parent (Duvall and Zint, 2007).
Table 7

Teaching Schedule and Number of Student Participants per Grade Level

<table>
<thead>
<tr>
<th>Date</th>
<th>School</th>
<th>Grade</th>
<th>Teacher</th>
<th>Number of Classes</th>
<th>Number of Student Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/14/2012</td>
<td>Russell</td>
<td>First Grade</td>
<td>Christina</td>
<td>5</td>
<td>119</td>
</tr>
<tr>
<td>9/24/2012</td>
<td>Russell</td>
<td>Kinder</td>
<td>Shane</td>
<td>5</td>
<td>83</td>
</tr>
<tr>
<td>9/25/2012</td>
<td>Russell</td>
<td>Pre-K</td>
<td>Christina</td>
<td>5</td>
<td>83</td>
</tr>
<tr>
<td>9/26/2012</td>
<td>Russell</td>
<td>Fourth Grade</td>
<td>Shane</td>
<td>6</td>
<td>103</td>
</tr>
<tr>
<td>9/26/2012</td>
<td>Russell</td>
<td>Second Grade</td>
<td>Alice</td>
<td>3</td>
<td>74</td>
</tr>
<tr>
<td>9/28/2012</td>
<td>Russell</td>
<td>Fifth Grade</td>
<td>Alice</td>
<td>4</td>
<td>112</td>
</tr>
<tr>
<td>10/01/2012</td>
<td>Henderson</td>
<td>Second Grade</td>
<td>Alice</td>
<td>4</td>
<td>100</td>
</tr>
<tr>
<td>10/02/2012</td>
<td>Henderson</td>
<td>Third Grade</td>
<td>Christina</td>
<td>5</td>
<td>69</td>
</tr>
<tr>
<td>10/03/2012</td>
<td>Henderson</td>
<td>Fourth Grade</td>
<td>Shane</td>
<td>5</td>
<td>109</td>
</tr>
<tr>
<td>10/04/2012</td>
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<td>Fifth Grade</td>
<td>Shane</td>
<td>5</td>
<td>79</td>
</tr>
<tr>
<td>10/09/2012</td>
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<td>Christina</td>
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</tr>
<tr>
<td>10/09/2012</td>
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</tr>
<tr>
<td>10/15/2012</td>
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<td>Pre-K and Kinder</td>
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<td>64</td>
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<td>Christina</td>
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<td>53</td>
</tr>
<tr>
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<td>Third Grade</td>
<td>Shane</td>
<td>3</td>
<td>66</td>
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<tr>
<td>10/17/2012</td>
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<td>Shane</td>
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<td>34</td>
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<tr>
<td>10/18/2012</td>
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<td>Shane</td>
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<tr>
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<td>EC</td>
<td>Shane</td>
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<tr>
<td>10/22/2012</td>
<td>Jordan</td>
<td>Fifth Grade</td>
<td>Alice</td>
<td>5</td>
<td>69</td>
</tr>
<tr>
<td>10/23/2012</td>
<td>Jordan</td>
<td>Fourth Grade</td>
<td>Christina</td>
<td>4</td>
<td>64</td>
</tr>
<tr>
<td>10/24/2012</td>
<td>Jordan</td>
<td>Third Grade</td>
<td>Shane</td>
<td>5</td>
<td>78</td>
</tr>
<tr>
<td>10/25/2012</td>
<td>Jordan</td>
<td>Second Grade</td>
<td>Shane</td>
<td>5</td>
<td>86</td>
</tr>
<tr>
<td>10/29/2012</td>
<td>Jordan</td>
<td>First Grade</td>
<td>Alice</td>
<td>4</td>
<td>125</td>
</tr>
<tr>
<td>10/30/2012</td>
<td>Jordan</td>
<td>Kinder</td>
<td>Christina</td>
<td>3</td>
<td>63</td>
</tr>
<tr>
<td>10/31/2012</td>
<td>Jordan</td>
<td>Pre-K</td>
<td>Shane</td>
<td>4</td>
<td>81</td>
</tr>
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High Efficiency Toilet Voucher Redemption Data

Within the entire research area, a total of 195 homes redeemed toilet vouchers prior to May 2012 and were included in the pre-intervention water data since they were part of the baseline water use of the research area (see Figure 8). A total of 73 homes redeemed toilet vouchers in the research area during the intervention year, between May 2012 and April 2013, and were removed from the analysis using address geocoding in ArcMap™ 10.1. Since the high-efficiency toilet data was removed from the analysis, the hypothesis that high-efficiency toilets did not influence the amount of water used in the areas that have received the hands-on, inquiry-based water conservation education program was not rejected. The analysis then focused on the water use in single-family homes that did not redeem a voucher for a high-efficiency toilet.

Figure 8. Homes with redeemed toilets prior to intervention year (baseline).
Results of Hypothesis Testing

The reported demographic data for each school showed a similarity in race/ethnicity between three of the four schools in the study. Henderson Elementary, Jordan Elementary, and Russell Elementary each reported a majority race/ethnicity of Hispanic students, with each percentage of students being over 80% of the entire population. Carpenter Elementary was not similar and reported a majority African American race/ethnicity of 53.2% of the population, with 46.5% of the students being classified as Hispanic. In order to account for the possible variable of a noticeable racial/ethnic difference in the student population at Carpenter Elementary, the analysis proceeded with only water use data from single-family homes within the Henderson, Jordan, and Russell school zones as they shared the same ethnic majority. The addresses of the homes located in the Carpenter Elementary school zone were plotted on a map using ArcMap™ 10.1 and were then removed from the analysis. The research area included in the analysis can be seen in the map in Figure 9.

Mean monthly water use, in gallons, for single-family homes in each of the three school zones was analyzed in the research area before the intervention year, from May 2011 – April 2012 and during the intervention year, from May 2012 – April 2013. Water use data for a total of 3,934 homes was reported in the entire research area by DWU for the pre-intervention year, which was May 2011 – April 2012. Water usage data for a total of 3,943 homes was reported in the entire research area by DWU for the intervention year, which occurred May 2012 – April 2013. Figure 10 shows the single-family homes plotted on a map of the research area. Each dot represents a single-family home and 12 months of reported data.
Figure 9. Map of research area included in analysis.
Figure 10. Map of single-family homes in research area.
The City of Dallas Water Utilities collects water use data for each of its customers in units of gallons. According to Dr. F. Wynn at the City of Dallas, the water meter reads for customers are not always collected each month or are not reported with the actual number of gallons used. When the data is not reported, or when no water is used, monthly data points may include values of zero, even if water was actually used. Dr. Wynn explained that the technology that is used to record the data may be the cause of the zero values and he cannot explain whether no water was used in the single-family home or if there was a data error. Dr. Wynn also mentioned that the technology used to report the data seems to improve each year and less values of zero are reported in successive years (personal communication, July 10 2012). Included in the reported water data from DWU were values of zero for many months for single-family homes in the research area. An example of the raw data can be seen in Appendix A.

Before a statistical analysis could be conducted, the researcher had to visually inspect the raw water data reported by DWU for the inclusion of zero-values for each single-family home in each school zone. Using a “count-if” statement in Microsoft Excel®, the researcher was able to label the number of months with zero-values that each single-family home contained for pre and post intervention data. Since it was not possible to determine the reason for the zero value, the researcher established a rule that in order to be included in the data, a single-family home in the research area must have at least three-fourths, or nine months of non-zero water use values to be included in the study. If a home had more than three months which showed zero gallons were used, that home was excluded from the evaluation. Each school zone’s water use data that included at least 9-months of water use was analyzed and Table 8 shows the total
number of homes in the research area and the number of homes that met the criteria of at least nine months of non-zero water data values, which were used in the analysis.

Table 8

*Number of Homes with Less than or Equal to Three Zero-values*

<table>
<thead>
<tr>
<th>School Zone</th>
<th>Total Number of Homes Including zero-values per year</th>
<th>Total Number of Homes Including three or less zero-values per year</th>
</tr>
</thead>
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<tr>
<td>Henderson Elementary</td>
<td>1,456</td>
<td>1,456</td>
</tr>
<tr>
<td>Jordan Elementary</td>
<td>752</td>
<td>755</td>
</tr>
<tr>
<td>Russell Elementary</td>
<td>1,726</td>
<td>1,732</td>
</tr>
</tbody>
</table>

An overview of the pre and post intervention yearly trend of the monthly water use for all three school zones is shown in Figure 11. For the sake of clarity, additional separate graphs have been included for Henderson Elementary (see Figure 12), Jordan Elementary (see Figure 13), and Russell Elementary (see Figure 14). Figure 15 shows the results for each school zone for pre intervention and post intervention.
Figure 11. Pre and post intervention comparison of mean monthly water use.
Figure 12. Pre and post intervention water use for Henderson Elementary.
Figure 13. Pre and post intervention water use for Jordan Elementary.
Figure 14. Pre and post intervention for Russell Elementary.
Figure 15. Pre and post intervention mean monthly water use.
The yearly water use in the research area was compared for the periods May 2011 – April 2012 (pre-intervention) and May 2012 – April 2013 (post intervention). The mean monthly water use in the research area prior to the intervention was 6,891.147 gallons. During the year of the educational intervention, the mean monthly water use was 6,389.548 gallons (see Table 9). A statistically significant reduction in water use, of 501.600 gallons per month, occurred during the year of the educational intervention in the research area, rejecting the first null hypothesis that a change in water use would not be evidenced in single-family homes that have received hands-on, inquiry-based water conservation education over the course of one calendar year (independent t-test, \( p < 0.001 \)).

Table 9

*Comparison of Monthly Water Use (in gallons)*

<table>
<thead>
<tr>
<th>Year</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
<th>t</th>
<th>df</th>
<th>p</th>
<th>95% confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 2011 – April 2012</td>
<td>16,788</td>
<td>6,891.147</td>
<td>6,830.636</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(pre intervention)</td>
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<td></td>
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</tr>
<tr>
<td>May 2012 – April 2013</td>
<td>44,976</td>
<td>6,389.548</td>
<td>6,015.980</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(post intervention)</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>8.872</td>
<td>61,738</td>
<td>&lt;0.001</td>
<td>390.789 – 612.410</td>
<td></td>
<td></td>
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</tbody>
</table>

*Note:* The n-values represent months of water use for one calendar year per single-family home (i.e., 44,976 months of water data represents a year of water use for 3,748 homes).
A one-way ANOVA was used to analyze the differences between the individual school zones in the research area (see Table 10). Table 11 includes data from the analysis, which shows the pre and post intervention mean monthly water use in single-family homes in each school zone. Each school zone showed a statistically significant reduction in water use when compared to itself before receiving the hands-on lessons and after receiving the hands-on lessons (Holm-Sidak method, $p<0.001$).

Table 10

ANOVA Results for Comparison of All School Zones

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>7</td>
<td>2.509E+10</td>
<td>5.018E+09</td>
<td>129.732</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Residual</td>
<td>61734</td>
<td>2.388E+12</td>
<td>3.868E+07</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>61739</td>
<td>2.413E+12</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 11

Monthly Mean Water Use per Year per School Zone (in gallons)

<table>
<thead>
<tr>
<th>Area</th>
<th>Mean Monthly Water Use May 2011 – April 2012 (pre intervention)</th>
<th>Mean Monthly Water Use May 2012 – April 2013 (post intervention)</th>
<th>Difference of Means</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Margaret B. Henderson</td>
<td>7,810.333</td>
<td>7,120.729</td>
<td>689.604</td>
<td>7.029</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Barbara Jordan</td>
<td>6,733.810</td>
<td>6,163.629</td>
<td>570.181</td>
<td>5.167</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Clinton P. Russell</td>
<td>6,260.092</td>
<td>5,862.196</td>
<td>397.896</td>
<td>4.454</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
Figure 16 shows a bar graph of the mean monthly water use for each school before and during the intervention. Once again, homes in each school zone showed a statistically significant reduction in water use during the intervention year. These findings rejected the second null hypothesis that a change in water use would not be evidenced in single-family homes within individual school zones that have received hands-on, inquiry-based water conservation education over the course of one calendar year \( (t\text{-test}, p<0.001) \).

**Figure 16.** Mean monthly water use per school.
Figure 17 shows a line graph of the pre and post intervention mean monthly water use in the individual school zones.

**Pre and Post-Intervention Mean Monthly Water Use per School Zone per Year**

![Graph showing pre and post-intervention mean monthly water use per school zone.](image)

**Figure 17.** Pre and post-intervention mean monthly water use per school zone

**Summary**

This chapter addressed the research sample, data collected, and the statistical tests performed. Null hypotheses 1 and 2 were rejected based on the analysis of water use data, while the study failed to reject null hypothesis 3. Chapter 5 provides a summary of the study, implications of the findings, and recommendations for future research.
CHAPTER 5
DISCUSSION AND RECOMMENDATIONS

This research addresses the gap in the literature which called for the analysis of empirical water use data when assessing whether or not an EE water conservation program has an effect on behavior change (Thompson et al., 2011; Clark and Finley, 2008; Clutts, Saltz, and Elser, 2008; Middlestat et al., 2001; Michelsen, McGuckin, and Stumpf, 1999; Dziegielewski, 1990; Birch & Schwaab, 1983; Hamilton, 1985).

As previously mentioned in Chapter 2, researchers in the field of EE have drawn on behavioral research to inform the creation of campaigns and programs that change and affect participant’s knowledge, attitude, and behaviors (Hungerford and Volk, 1990; Heimlich and Ardoin, 2008; Leeming and Porter, 1997; Legault and Pelletier, 2000; Ballantyne, Fein, and Packer, 2000). Hungerford and Volk (1990) reported that a behavior change may not stem from a linear change in knowledge and affect alone, but from a variety and hierarchy of variables, such as commitment, ownership, skill set, and self-efficacy. Heimlick and Ardoin (2008) urged practitioners to encourage a level of commitment from participants when attempting to measure changes in knowledge, attitudes, and especially behavior. While some changes in action and behavior have not been realized to date (Moore and Crompton, as cited in Schultz, 2011), more studies have shown positive effects of EE programs on behavior using a variety of measurement instruments (Alp, Ertepinar, Tekkaya, and Yilmaz, 2008; Kruse and Card, 2004; Grodzinska-Jurczak, Bartosiewicz, Twardowska, and Ballantyne, 2003; Wagstaff and Wilson, 1998; Leeming et al., 1997; Smith-Sebasto, and Fortner, 1994; Ramsey, 1993; Ramsey and Hungerford, 1989). From those EE studies and literature from water
resource management that reported positive results on changing behavior, an intriguing
caveat emerged. Researchers were cautioned about the use of self-report data as a
measurement instrument, as it may not portray an accurate depiction of actual behavior
(Martinez-Espineria, Garcia-Valinas, and Nauges, 2014; Sarabia-Sanchez, Rodriguez-
Sanchez, and Hyder, 2014; Camargo and Shavelson, 2009; Kruse and Card, 2004;
Howard and McGregor, 2000; Berk, Schulman, McKeever, and Freeman, 1993;
Dziegielewski, 1990). And so, based on the work and recommendations of other
researchers in the field of EE and water resource management, this study did the
following:

• Employed an education program, the EEI, in Grades K – 5 that used
  methods and teaching styles that encouraged a voluntary commitment
  from students
• Increased the skill set and self-efficacy of students by teaching them
  specific water conservation behaviors they could use at home
• Measured changes in water use using empirical data in the form of water
  meter records

Some researchers in the field of EE began to study not only the effects of a
program on behavior change in the student participants, but the transfer of knowledge,
atitudes, or behavior changes that can occur from a child to an adult (Vaughan, Gack,
Solorazano, & Ray, 2003; Ballantyne, Fein, & Packer, 2001; Legault & Pelletier, 2000;
Ballantyne, Connell, & Fein, 1998; Leeming, Porter, Dwyer, Cobern, & Oliver, 1997;
Uzell, 1994; Sutherland & Ham, 1992). In a review of those studies, Duvall and Zint
(2007) reported limitations and recommendations that practitioners and researchers
could heed in order to create programs that may be successful in encouraging intergenerational transfer (see Table 2). Based on the work of the aforementioned researchers, this study measured the effect of the EEI K – 5 water conservation lessons on behavior change and was able to address the limitations and recommendations (see Table 2) set forth by Duvall and Zint (2007). The inclusion of take-home items (see Figure 3) may have increased discussions and information transfer between the children and parents or other family members. Because the reduction in water use for each single family-home, overall and within each individual school zone, was greater than 350 gallons per month, it may be possible that intergenerational transfer of the water conservation behaviors and lesson concepts occurred between the child and family, resulting in larger reductions in water use than could be attributed to an individual child alone. The results from this study indicate that the EEI may have been successful in encouraging intergenerational transfer between the students and other family members in their home.

Finally, because few evaluations of water conservation programs exist (Cutts, Saltz, and Elser, 2008; Clark and Finley, 2008; Michelsen, McGuckin, and Stumpf, 1999; Howard and McGregor, 2000) this study is relevant and important, as it addresses a gap in the literature and it provides researchers, practitioners, and professionals information about how to measure the effects of a program using empirical data. Results revealed a significant reduction in water use in areas that received hands-on, inquiry-based lessons and suggest that the EEI may play a role in decreasing water use for residential purposes.
Conclusion

Water conservation infrastructure, campaigns, education programs, management strategies, and incentives are necessary for citizens globally, nationally, and in Texas to mitigate and adapt to changing water supplies and sources (Matthews et al., 2011; Corral-Verdugo et al., 2003; Leopold, 1958). A shortage of water in any area inhabited by humans, plants, and animals poses a serious problem, and so the public, not just the scientific community, should become familiar with general principles of water to aid in decision-making and understanding of conservation (Leopold, 1958). Every living thing depends upon water for survival, so it should follow that education about water and how to conserve water are necessary not only for the continuation of life as we know it, but for the future of the generations that are to come.

Evaluations of water conservation education programs are necessary to determine best practices, teaching methods, possible confounding variables, and impact on actual water use. Past studies have measured the effectiveness of water education programs on the cognitive, affective, and behavioral domains by using various methods, such as self-report, but this study fills a gap in the literature because it not only controls for variables which may contribute to water use, but it also uses empirical data to measure the impact of education on behavior. The results showed statistical reductions in water use within single-family homes that received water conservation education lessons in the research area as a whole and also within single-family homes within individual school zones. The mean reduction in use for the entire area was approximately 502 gallons per month, which would equate to a savings of approximately 6,024 gallons per year for each single-family home, or a total savings of
22,577,952 gallons of water per year for the entire area. This research is applicable to teachers, educational researchers, and water management professionals who are interested in any of the following:

- To create an educational water conservation program
- To evaluate the effectiveness of a program using empirical data
- To inform the decision to appropriate funds for educational versus informational water conservation programs

Limitations

An intriguing limitation of this study is that the analysis of the water data included anonymous single-family homes located within three school zones. At the time, the researcher had no way to identify or track the individual homes of the students who participated in the EEI lessons. Although it can be assumed that the students who were taught the EEI lessons lived in a portion of the homes included in the study, it was not possible to directly match the students’ addresses with the addresses provided in the DWU water use data. The question becomes, would school administrators be willing to provide address information of the students who participated in EEI lessons so that an even more accurate analysis of residential water use may be conducted?

Another potential limitation of the study is the way water use data was reported by DWU. As referenced in Chapter 3, the water use data included values of zero which were not explained by the staff member at Dallas Water Utilities or by the data itself. Establishing criteria to include only a portion of a year’s worth of water data was sufficient for the analysis in this study however, due to the large sample size of monthly water use records for single-family homes in each school zone.
Recommendation for Future Study

An avenue for further research would be to focus even more specifically on the homes of the students who received the water conservation education program. As a sort of longitudinal cohort study, with the support of school administrators, researchers could follow a grade-level group of students at an experimental and control school, beginning in kindergarten, teaching them each and every year through 5th grade. This would allow for the collection of water use data for each home for each year the students received the education and an analysis could be conducted comparing each of the students by their year in school as well as overall. Questions that this type of research could attempt to address could include:

- Do students save water after participating in a hands-on, inquiry-based water education program for six years?
- During which year are students more likely to begin saving water at home after participating in a hands-on, inquiry-based water education program?
- What grade level should a water conservation education program begin to see a reduction in water use in single-family homes?
- Are there differences in the amount of water used by students in different grade levels?
- Are there differences in the amount of water used by students in the same grade level?
- Does age play a role in influencing water conservation behavior?
- Does gender play a role in influencing water conservation behavior?
- Does race/ethnicity play a role in influencing water conservation behavior?
Another avenue for future research is replication of the program in another municipality within the state, domestically, and internationally. The City of Dallas Environmental Education Initiative was created as a model that could be replicated in various large urban cities. Additionally it can be adapted to fit the specific needs of a community in regards to water resources, educational standards, and community demands. Because Dr. Thompson and the UNT team have received the third multi-year contract issued by the city of Dallas, future research avenues are both practical and promising.

A hands-on, inquiry-based, K-12 environmental education program that teaches water issues and specific water conservation behaviors in classrooms, such as the City of Dallas Environmental Education Initiative, appears to be playing a role in decreasing the amount of water citizens use for residential purposes. In addition, the ability to measure a water conservation education program’s effect on behavior change, specifically water use, is both relevant and important in the sustained conservation of our world’s most precious resource.
APPENDIX

EXAMPLE OF DWU RAW WATER USE RECORDS
<table>
<thead>
<tr>
<th>Code</th>
<th>City</th>
<th>House Number</th>
<th>Type of Premise</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
</tr>
</thead>
<tbody>
<tr>
<td>7524</td>
<td>DALLAS</td>
<td>13000</td>
<td>Single Family Residential</td>
<td>1900</td>
<td>1900</td>
<td>1900</td>
<td>1900</td>
<td>1900</td>
<td>1900</td>
<td>1900</td>
<td>1900</td>
<td>1900</td>
<td>1900</td>
</tr>
<tr>
<td>7524</td>
<td>DALLAS</td>
<td>14000</td>
<td>Single Family Residential</td>
<td>1800</td>
<td>1800</td>
<td>1800</td>
<td>1800</td>
<td>1800</td>
<td>1800</td>
<td>1800</td>
<td>1800</td>
<td>1800</td>
<td>1800</td>
</tr>
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