Implementing Sustainability through Student Engagement and Authentic Mathematical Practices

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The primary aim of this article was to examine how to minimize waste in a school setting by reducing, reusing, recycling, and composting waste products while providing students with real-life mathematical practice. The goal was to identify lasting changes that support student engagement with the integration of mathematical content. Through the Washington Green Schools certification process, an assessment examined how much and what types of waste products were disposed of daily. This study identifies what changes can be implemented to make lasting changes while providing authentic mathematical learning.

INTRODUCTION

Providing students with educational opportunities through authentic learning experiences can promote lifelong skills. Because there is a need to understand how current actions impact issues of tomorrow, it is important to educate today's youth to take care of the environment by making small sustainable changes. Sustainability creates and maintains the conditions so there will be enough resources to protect the environment for years to come (Environmental Protection Agency, 2017). To promote practical sustainability and waste reduction there must be individuals willing to do what is best for communicating the importance of environmental responsibility to those within the school community (Redman, 2013).

Even though environmental education may not be a required content area to teach in most grades, using the data from a waste reduction program would be an innovative way for students to learn math. When teachers incorporate real-life mathematical learning into their teaching, students acquire the necessary mathematical knowledge and skills that lead to enduring understanding gained through ongoing practices. Teachers should plan activities that allow students to participate in the mathematical experiences, so they encounter a familiar concept in a new and different context (Sammons, 2011).

Students must learn mathematics with understanding, actively building new knowledge from experience and prior knowledge (National Council of Teachers of Mathematics, 2000). For students to make meaningful connections when solving mathematical problems, teachers can integrate the authentic data from their waste reduction program into core content areas such as measurement, data collection, numeric relationships, numbers & operations, and number sense. The stronger the connections are among related ideas; the more opportunities students will have to develop a deeper and richer understanding of the math concepts.

Designing a framework upon which all students can be active participants in a school-wide waste reduction program allows for actual learning to take place. Supporting project-based learning lets students build the skills and confidence to embrace the environment. Cross curricular activities prepare students to use mathematics beyond the classroom. When students reflect on their own experiences, they are more

likely to develop an understanding of math concepts in contexts that are meaningful for them (Sammons, 2011). Using real mathematical data collected from the school waste and recycling program result in students making lasting changes by implementing sustainable practices.

Teachers can investigate how to minimize waste at school as well as use the authentic data to support mathematical content. A school-wide approach is key for all stakeholders to work together to make a lasting change (Griffiths, Richards, & Winters, 2007). To reduce environmental impact through waste reduction, every person can make a difference by using fewer resources or using materials more than one time. Changing individual behaviors is essential to achieving a promising green future and a central motivation of sustainable education (Frisk & Larson, 2011).

Why is conservation education necessary and how can teachers implement this topic into core content activities? Conservation education supports academic success meeting students' current and future needs (Office of Superintendent of Public Instruction, 2015). School settings have the potential for creating change through promoting conservation. Knowledge is power when it comes to making change. Developing quality educational systems require students to adapt and learn continuously (Frisk & Larson, 2011).

Each action of today is a step towards creating a better tomorrow (United Nations Educational, Scientific and Cultural Organization, 1997). The principles and practices developed for long-term effects on the environment provide students with real-life mathematical practices while promoting green solutions. Because of this, Washington State developed, implemented, and supported environmental sustainability needs in education programs (Nolet & Wheeler, 2010).

PURPOSE

The purpose was to identify lasting changes that support implementation of mathematical content and encourages authentic learning. The intent was to help students develop environmental friendly habits by taking an active role in what they learn and can do. After establishing a need for this study, the following questions were asked. What steps are necessary to reduce waste at school? How does participation in a school-wide recycling program provide students with real-life mathematical practices?

Each year schools accumulate tons of waste from paper to electronics to food, making them an ideal intervention point for targeted environmental change. Educational institutes have the same stumbling blocks as any other organization attempting to create an organizational culture that values natural resources (Schelly et al., 2012). That is why there is a need to model the desired behaviors to create opportunities for lasting change leading to altering habits focusing on sustainability.

Past research has indicated that recycling can benefit a community and help sustain the environment for future generations (Environmental Protection Agency, 2017). School communities can lead the way toward conservation by providing a supportive atmosphere for sustainable behaviors (Redman, 2013). Conservation education should be infused into the core curriculum and require a new way of teaching, learning, and thinking about the content (Nolet & Wheeler, 2010).

Making conscious decisions to teach more sustainable practices, teachers face challenges in preparing students to be conscientious citizens. Instilling environmentally friendly behaviors, attitudes, and practices from a young age cannot only have an immediate impact but long-term benefits to society by molding a generation that will be better stewards of natural resources. Incorporating a waste reduction theme as part of a math or reading curriculum engages students in their understanding of waste within the context of sustainable living (Griffiths, Richards, & Winters, 2007). While integrating content areas together, teachers must help students be confident, engaged mathematics learners (National Council of Teachers of Mathematics, 2000). Achieving changes in behavior will come from a shift in values and awareness (United Nations Educational, Scientific and Cultural Organization, 1997).

Teachers who incorporate conservation concepts into their classrooms can face obstacles such as lack of time to learn something new or the time to introduce an idea outside of the core curriculum (Church & Skelton, 2010). If math teachers have the necessary resources to support integrated environmental learning opportunities, then students can develop the knowledge and understanding that prompts them to

take action that promotes waste reduction. When teachers integrate mathematics with sustainability the students' interest increases as they recognize how mathematics is connected and relevant to their own life experiences (Sammons, 2011). The Next Generation Science Standards allows for teachers to express key aspects of environmental sustainability and mathematics for young students (Office of Superintendent of Public Instruction, 2015).

School settings are viewed as centers for change which can lead to a revolution in maintaining the environment. It is important to have teachers and staff as role models to motivate students about environmental conservation (Higgs & McMillan, 2006). By getting the school leaders to model conservation behaviors and positively reinforce those behaviors in others, there is greater potential for utilizing social knowledge as a motivation tool rather than a barrier (Redman, 2013). Collaboration is critical for understanding and exploring future alternatives in ways that are conducive for action (Wiek, Withycombe, & Redman, 2011).

A greener school empowers students to make a change that will stay with them for life (Green Schools Initiative, 2014). Providing students with a supportive environmental infrastructure for taking action is vital to maintaining change in the future (Redman, 2013). When seeing the actions of others, the students become better prepared to lead more sustainable lifestyles while making a difference in their school culture (Higgs & McMillan, 2006).

Community Support and Resources

Given that 1.2 million people spend their days in K-12 schools in Washington State, these institutions can play a significant role in advancing sustainability awareness and interventions in a community (Washington Green Schools, 2017). Professional organizations can provide leadership and expertise to support authentic learning (National Council of Teachers of Mathematics, 2000). Developing a strong partnership with local organizations can help teachers explain conservation and sustainability to young students. With the guidance of organizations like Washington Green Schools, Waste Management, and the Public Utility District's Education Team, teachers have educational materials available to integrate into their core content lessons. Teachers can provide a framework using a researched-based program to help embed the fundamental principles of implementing a waste reduction program. By infusing sustainable behaviors into daily activities, a school setting requires the support of all stakeholders within the school culture (Schelly et al., 2012).

Washington Green Schools is a nonprofit organization dedicated to helping educational settings to create conservation practices. Teachers and staff from the Washington Green Schools organization have developed an environmental conservation model to assist and support school communities. Best practices included moving beyond conservation knowledge while inspiring and strengthening concepts thinking toward the future (Shriberg & MacDonald, 2013). Students gain the skills and hands-on learning opportunities needed to be successful because programs like Washington Green Schools works to give them tools needed to succeed. As a result, Washington Green Schools provides opportunities for students and school communities to create lasting educational experiences through conservation changes (Washington Green Schools, 2017).

The Waste Management website provides free online educational resources, videos, and craft ideas to expand everyone's understanding of issues related to recycling and natural resource recovery. Their mission is to reduce consumption, reuse products, and recycle waste materials that help to conserve natural resources (Waste Management, 2017). Solving conservation problems and generating sustainability opportunities requires active collaboration (Wiek, Withycombe, & Redman, 2011). Working together to reduce the depletions of natural resources, waste reduction systems can result in environmental benefits (Environmental Protection Agency, 2017).

To develop lifelong changes in young people, Snohomish County Public Utility District's Education Team has made a commitment maximizing resources and offering a school-to-world connection through recycling assemblies, classroom workshops, and student learning activities (Snohomish County Public Utility District, 2017). Conservation concepts can provide notable contexts for developing the skills of critical thinking, collaboration, and communication (Church & Skelton, 2010). Thus, the journey begins

by identifying the kinds of actions that can be implemented to make the biggest improvements to make lasting change in the school community.

Certification Process

The Washington Green Schools program provides educational resources to public and private K-12 schools. This program outlines ways to inform teachers and school leaders about the process to create lasting change reducing the schools' environmental footprint. The Washington Green Schools certification program promotes and acknowledges long-term action for lasting changes in six environmental categories.

The first requirement for becoming certified as a green school through Washington Green Schools was to create a school Green Team. A classroom teacher became the facilitator for the Green Team along with five certificated staff, two classified staff, the principal, and nine fourth-grade students. After forming the Green Team, the group organized efforts associated with environmental responsibility. Then, a discussion began to initiate the process of establishing a school-wide mission to implement lasting change. During the beginning stage of this movement, the Green Team members created a sense of teamwork and the Green Team students became leaders. The demographics of the Green Team students consisted of seven girls and two boys. Of the nine students, six students were Hispanic, two students were Caucasian, and one student was Asian.

The Green Team met every two weeks. They encouraged one another to think of creative ideas to reduce waste that would benefit the environment. Their school-wide mission was to make lasting change by decreasing the amount organic waste and recyclables getting placed in landfills while increasing composting and recycling. However, the achievement of such goals within the school environment needed participation, support, planning, and fortitude from all stakeholders (Colliver, Bishop, & Caristo, 1999). Building a Green Team demonstrated that teamwork increased students' awareness of environmental issues empowering them to be leaders while working together to decrease waste (Green Schools Initiative, 2014). The overall message from the team was to create lasting changes within an environmentally friendly school community.

Waste and Recycling Assessment

Step two of the Washington Green Schools certification program was to select one of six environmental categories to assess in the school setting. The Green Team chose the Waste and Recycling Assessment and Characterization Audit. This category gave an overview of the status of the school's waste, recycling, and composting practices in the cafeteria, classrooms, and office area. Some questions from the guide were:

1. How many garbage dumpsters and containers does your school have?
2. How much waste does your school dispose of in one month?
3. After sorting your waste, what percent of garbage could have been recycled or composted?
4. What does your school pay for recycling services?

METHODS

The intent of this study was to determine if the 770 students (374 girls and 396 boys) and 72 staff members could reduce waste at school. This Title I elementary school had 77% of the students receiving free or reduced-priced meals and 36% of the students were transitional bilingual.

A classroom teacher, custodian, and three of the Green Team students conducted a Waste and Recycling Assessment and Characterization Audit. The materials that students used for this audit were a digital scale, calculator, 5-gallon buckets, the assessment sheet, and bins that contained each waste product. The assessment provided specific guidelines for the Green Team to follow. There was a random selection of garbage bins collected in the school cafeteria, classrooms, and main office. Each bin was weighed by the students and recorded on the assessment sheet. The Green Team used various mathematical techniques to calculate the results with one student verifying the data using a calculator.

This activity provided students with genuine data making the content more relevant. The students used the pre-assessment data and identified the percentage of specific waste products from the three areas within the school. The teachers at the elementary school had access to this information and created their own mathematical problem-solving activities for their students.

The week following the assessment audit, the staff and students were trained to reduce, reuse, recycle, and compost waste products. The students from the Green Team created signage for each new waste bin in the cafeteria. At the end of each month, students used a post-assessment to examine the data from the waste bins. The students did a comparison between the pre-assessment and the post-assessments from the cafeteria. This information was shared with teachers and support staff to allow for relevant data to be integrated into the classroom. The data revealed a notable decrease in waste and an increase in recycling and composting.

RESULTS

The Waste and Recycling Assessment and Characterization Audit provided a snapshot of how much and what types of waste products were identified in the random selection of garbage bins from the cafeteria, main office, and classrooms. After the students recorded the weight of the waste materials, each item was sorted into recyclables, compostable, and garbage. The sorted contents were weighed again with the students recording the common items. This information helped the Green Team look for opportunities to reduce or prevent waste.

The Green Team established a baseline of waste generated at school. This measurement revealed that each month the school disposed of 40-cubic yards of garbage, 20-cubic yards of recyclables, and 3-cubic yards of compost materials. The students graphed this information and shared the data with the administration.

There was one key finding from the cafeteria that stood out to the Green Team members. After sorting and weighing the waste product from three random garbage bins, there were 45 lbs of compostable materials, 111 lbs of recyclable materials, and 12 lbs of garbage collected. Thus, the data assessment showed 93% of the products in the garbage were recyclable or compostable. From the waste products collected, 66% was recyclable, 27% was compostable, and only 7% was garbage. There were fifteen 44-gallon bins of garbage a day in the cafeteria. Examples of items put in the trash versus recycled or composted consisted of milk containers, juice containers, fruit, bread, napkins, juice pouches, and soda cans.

The information that the students' gathered revealed the current waste and recycling practices. Through the baseline assessment, the Green Team tracked changes, determined potential improvements, and prioritized goals. This authentic data was accessible for teachers to incorporate into their mathematics lessons. The teachers had their students calculate the percentage of waste from their classroom and compared to the average percentage waste of the school. Students created graphs and charts to represent their findings. Through hands-on activities, achieving high standards in mathematical called for active participation of teachers and students National Council of Teachers of Mathematics, 2000).

Implementation: Action Plan

To obtain a better understanding of barriers to recycling and composting, the Green Team completed the Washington Green Schools program criteria. To begin the Green Team members identified current recycling behaviors and tracked successes over time. After reviewing the assessment results, an action plan was created setting a school-wide goal to improve environmental practices. After the analysis, the Green Team decided that reducing waste in the cafeteria would be the first place to make an effective, lasting change. This lead to the third step of taking action that resulted in implementing change in the focus category.

The facilitator of the Green Team educated and trained the Green Team students to recognize which waste products went into each waste bin. Modeling allowed students to emulate conservation concepts through continual direct observations that reinforced sustainable practices (Higgs & McMillan, 2006).

The students had multiple resources for understanding the recycling process which made it easy to adapt to change. After that, the students created signage to identify what products should go into each bin.

Fourth-grade students volunteered to be environmental ambassadors. These students had two main goals to meet. First, help other students with sorting waste materials as well as emptying recycle bins into a centrally located container. Diminishing confusion about what could be recycled and composted enhanced behavioral changes. Second, keep track of the data and report the findings to the classroom teachers. Then, the teachers could build prior knowledge or experiences to help students interpret and construct meaning from newly introduced ideas or concepts (Sammons, 2011). Learning with understanding was important to enable students to solve these types of problems that they are likely to face in the future (National Council of Teachers of Mathematics, 2000).

Verification: Making an Impact

When implementing a waste reduction program, it is essential to monitor areas that evolve over time. Thus, the fourth step to becoming certified through Washington Green Schools was verifying the focus area for lasting changes. The study revealed notable results in the first week of implementing changes.

The goal to reduce waste at the school by 50% evolved over three months. The 770 students and 72 staff members reduced the garbage each month. Factors that made a positive change were educating the student body on correct recycling and composting practices, prompting students to take ownership in the program, and using appropriate containers to dispose of the materials properly. The first thing that was evident in the school cafeteria was how students altered the way they disposed of their waste products. Best practice in recycling, reducing, reusing, and composting became an integral part of the school and cafeteria. The integration of two green compost bins, two blue recycling bins, and two red garbage bins made it easy to identify where to deposit waste materials. Also, there was a change to durable trays versus disposable Styrofoam trays as well as using bulk dispensers for condiments and other food products.

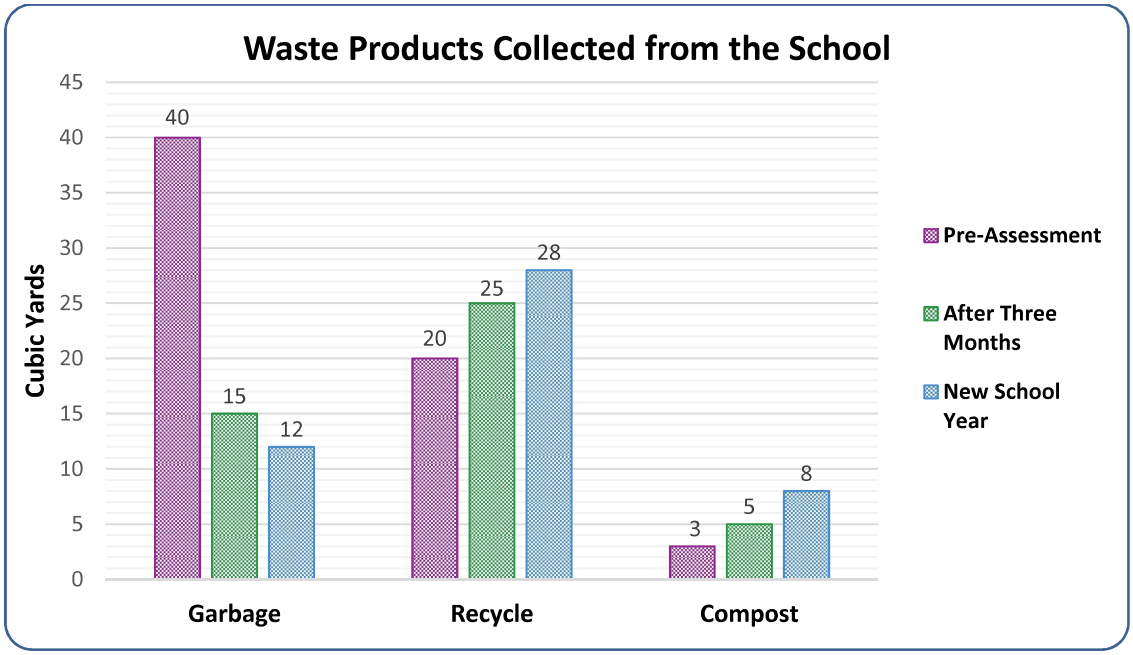
FINDINGS: ANAYLSIS OF DATA

Using a community supported recycling program helped identify what waste products were recyclable and determine what was considered actual garbage. The students used this mathematical data to examine the increase and decreases of the waste products. In just one month, the Green Team calculated that there were 12 lbs of drink pouches and 6 lbs of Lunchable plastic containers collected in the cafeteria. The garbage for the school decreased by 25% from 40-cubic yards of waste to 30-cubic yards. The monthly Waste Management bill decreased by 17% from $980 to $813 saving $167 the first month of implementing waste reductions. The school reduced the size of the garbage dumpster from a 6-yard dumpster to a 4-yard dumpster. Once again, the information collected allowed teachers to implement math content such as data collection, numeric relationship, measurement, and number sense into their math lessons. Students made the connection when the math was relevant to their learning (National Council of Teachers of Mathematics, 2000). This reinforced authentic mathematical practices for all grade levels.

The findings revealed in Figure 1 show the cubic yards of waste products that were recycled, composted, or disposed of as garbage. The Waste and Recycling Assessment and Characterization Audit was used as a pre-assessment baseline to calculate the initial amount of waste collected at school. With this information, students compared the amount of waste products after three months and at the beginning of a new school year. The garbage decreased 62% in three months from 40-cubic yards of waste to 15-cubic yards per month. Then, further decreased 70% from the initial baseline audit resulting in 12-cubic yards of waste at the end of the first month of the new school year. At the same time, recycling increased 25% in three months from 20-cubic yards to 25-cubic yards per month. At the end of the first month of the new school year, the recycling increased 40% from the initial baseline audit resulting in 28-cubic yards of recyclable materials. From the initial baseline audit, composting increased 66% from 3-cubic yards of materials each month to 5-cubic yards after three months. At the beginning of the new school

year further increased 166% from the initial baseline audit resulting in 8-cubic yards of compostable materials per month.

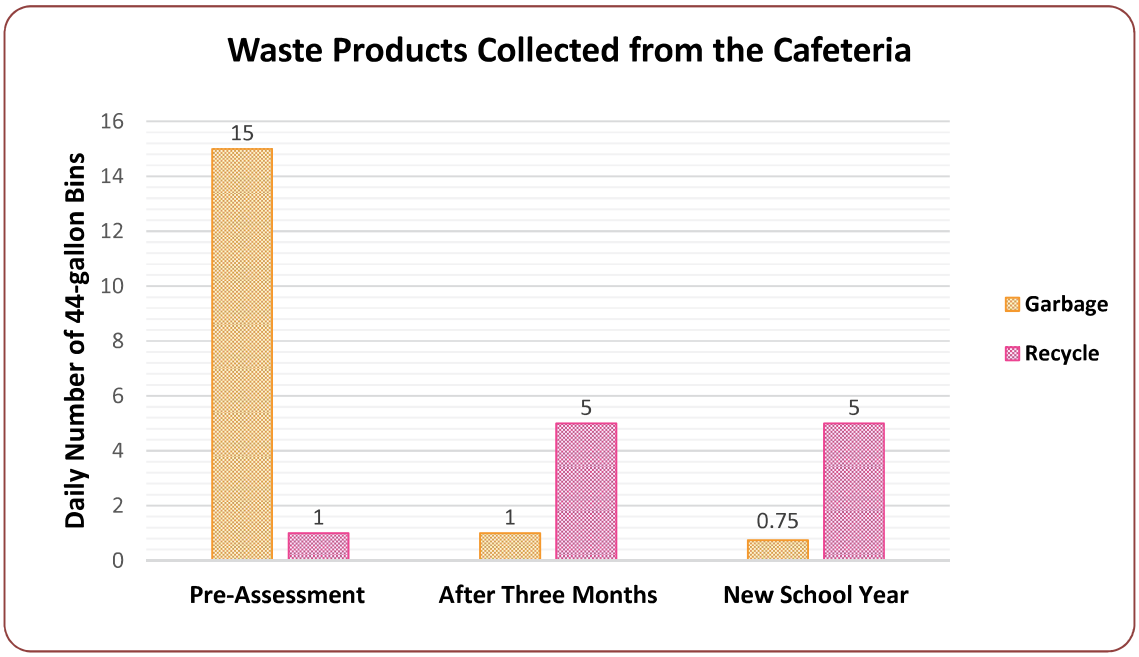
FIGURE 1
SCHOOL WASTE PRODUCTS



In Figure 2, data from the Waste and Recycling Assessment and Characterization Audit identified 15 44-gallon bins of waste products in the cafeteria per day. The information was used as the baseline to compare the initial amount of garbage and recycling produced after three months and at the beginning of a new school year.

There was a substantial reduction in garbage and a vast increase in recycling. At the end of the three months, the garbage in the cafeteria decreased to one 44-gallon bin a day and at the beginning of the new school year further decreased to less than one bin a day. The results revealed at the end of the third month that recycling increased 400% since the pre-assessment baseline and continued to maintain at this level at the beginning of the new school year.

FIGURE 2
CAFETERIA WASTE PRODUCTS PER DAY



Based on the findings, the biggest factors students noticed that influenced the decline in the garbage consumption in the cafeteria was recycling the milk and juice cartons as well as eliminating the Styrofoam trays. In addition, each bin in the cafeteria was color coded and marked clearly, so students knew where to put each waste product. To reduce items being accidently deposited in the incorrect waste bin, the Green Team students were available in the cafeteria daily to help other students with proper placement of waste products.

RESULTS

The fifth step in completing the certification was to share the journey and results with stakeholders to inspire others to make a difference in the community. Therefore, a school-wide assembly was organized inviting students, staff, parents, the media, and community members to attend the celebration of accomplishments. Students shared what they learned through artwork, poems, mathematical graphs, and skits. Real-world learning enabled students to apply theory to practice and built interpersonal skills critical for sustainability (Redman, 2013). Teachers provided relevant classroom activities by making connections between mathematics and daily events while allowing students multiple ways to demonstrate what they had learned (National Council of Teachers of Mathematics, 2000). Using the data collected by the Green Team, the classroom teachers incorporated probability, ratios, percentages, graphing, measurement, and problem solving into their math lessons. The data compiled from the school was more powerful for students to construct meaningful mathematical knowledge versus solving problems from a math textbook.

The final step in becoming certified was to review the Washington Green Schools report card, which was a summary page that tracked the progress in each category. After meeting the requirements and the lasting change verified, the application was submitted to Washington Green Schools for approval. Once successful, the school became certified through Washington Green Schools.

There are benefits to an eco-friendly school setting. Schools can conserve valuable resources, reduce environmental impact, save money, and cut down the amount of waste generated by recycling and

composting (Colliver, Bishop, & Caristo, 1999). Teachers in Washington State have the necessary resources to support integrated conservation projects while integrating mathematical concepts.

The significance of the study identified barriers and improvements that resulted in the recycling and composting of waste at an educational setting. The improved conservation practice reduced depletion of natural resources making it possible for ongoing changes. Stakeholders had an opportunity learn how to reduce waste and had mathematical data to support their claim. Through teaching, training, and teamwork steps were taken to making lasting changes while at the same time reinforce mathematical content in the classroom.

CONCLUSION

Since the implementation of the waste reduction program, the students at the school continue to reduce their environmental footprint. From the first three months of the recycling program, the Green Team documented the amount of each type of waste. As the new school year began, the Green Team continued to collect mathematical data examining any changes in the waste consumption. The data had been recorded and showed an improvement over the initial certification documentation. To date, there had been a decrease of waste products from 40-cubic yards of waste to 12-cubic yards a month. At the same time, recycling had increased from 20-cubic yards to 28-cubic yards of material and the compostable materials increased from 3-cubic yards to 8-cubic yards a month.

It takes a team to develop and implement change within the school community. The school's Green Team introduced something important which united the students and staff. Stakeholders acted resulting in behavioral changes that taught, modeled, and practiced waste reduction. Students applied the knowledge and skills needed to develop the ability to solve math problems inside and outside the classroom.

The outcome of this study provided insight on how students reduced waste within a brief time and continue to improve on their sustainability practices. Based on the results, a lasting change program can improve the way a school manages waste products. This short-term milestone aided in taking the first step to making a difference at a Title I elementary school. Best practices in the community will continue to evolve and allow for effective outcomes that translate into successes in education (Shriberg & MacDonald, 2013). In the future, recycling programs may help school communities to meet conservation needs and show greater improvements in becoming eco-friendly while reducing the depletion of natural resources.

REFERENCES

Church, W. & Skelton, L. (2010). Sustainability education in the k-12 classroom. *Journal of Sustainability Education, 2,* 3-6.

Colliver, A., Bishop, G, & Caristo, I. (1999). Green waste matters: A guide on green and organic waste management for schools. *Environment Australia, Canberra, ACT, 27-40.*

Environmental Protection Agency. (2017). Sustainability. Retrieved from epa.gov

Frisk, E. & Larson, K.L. (2011). Educating for sustainability: Competencies & practice for transformative action. *Journal of Sustainability Education, 2,* 12-15.

Green Schools Initiative. (2014). What is a green school? Retrieved from greenschools.net

Griffiths, M., Richards, M. & Winters, B. (2007). How to reduce, reuse and recycle waste in schools. Retrieved from http://www.sustainability.vic.gov.au/services-and-advice/schools/resources/waste-module-resources

Higgs, A. L. & McMillan, V. M. (2006). Teaching through modeling: Four schools' experiences in sustainability education. *The Journal of Environmental Education, 38,* 41-52.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics.* Reston, VA: Library of Congress.

Nolet, V. & Wheeler, G. (2010). Education for sustainability in washington state: A whole systems approach. *Journal of Sustainability Education, 2*, 1-6.

Office of Superintendent of Public Instruction. (2015). *Education for environment and sustainability*. Retrieved from k12.wa.us/EnvironmentSustainability

Redman, E. (2013). Advancing educational pedagogy for sustainability: Developing and implementing programs to transform behaviors. *International Journal of Environmental & Science Education, 8*(1), 2-26.

Sammons, L. (2011). *Building mathematical comprehension.* Huntington Beach, CA: Shell Education.

Schelly, C., Cross, J., Franzen, W.S., Hall, P. & Reeve, S. (2012). How to go green: Creating a conservation culture in a public high school through education, modeling, and communication. *The Journal of Environmental Education, 43,* 3-25.

Shriberg, M. & MacDonald, L. (2013). Sustainability leadership programs: Emerging goals, methods & best practices. *Journal of Sustainability Education, 5,* 16-18.

Snohomish County Public Utility District. (2017). Education. Retrieved from snopud.com/Education.ashx

United Nations Educational, Scientific and Cultural Organization. (1997). Educating for a sustainable future. Retrieved from unesdoc.unesco.org/images/0011/001106/110686eo.pdf

Washington Green Schools. (2017). Program information. Retrieved from wagreenschools.org

Waste Management. (2017). Don't let your garbage go to waste. Retrieved from wmnorthwest.com/educational/index.html

Wiek, A., Withycombe, L., & Redman, C. (2011). Key competencies in sustainability: a reference framework for academic program development. *Sustainability Science, 6*(2), 205-211.