Greenhouse Innovations in Schools: How to Stop Food and Water Shortages in the Present and in the Future

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Raton Innovative STEAM Team

Executive Summary

The purpose of the team's participation in this competition is to answer a specific topic regarding the national question presented by the "2019-2020 New Mexico Governor's STEM Challenge". The question presented was "How would you use science and technology to keep the world safe?" Raton Innovative STEAM Team (R.I.S.T.) answer to this question was to create a career pathway in Biosphere Engineering for 1st through 12th grade students. The purpose of this career pathway is to teach the importance of sustainable food production and water conservation. With national attention being focused on food and water insecurities, it is crucial that we educate ourselves on alternative strategies that will alleviate the food and water crisis. R.I.S.T. addressed the issues by using the school's greenhouse and teaching students in the Raton District how to grow their own food. R.I.S.T. took into account the constraints of the project and developed a model based off of those guidelines; the A.C.T.S. prototype was created not as a single solution to a problem, but rather a systemic part of our plan to create a career pathway based off of the current Health Care Career Pathway at Raton High School.

Keywords: Credegree, Biosphere Engineering, STEM, Food Scarcity, Water Scarcity, Career Pathway

Greenhouse Innovations in Schools: How to Stop Food and Water Shortages in the Present and in the Future

The essential question of "How will you use science and technology to keep the world safe?" led our team to create a pathway to teach children how to efficiently grow food. This would teach them how to conserve food and water and cut back on food and water scarcity. Our thought process was if we start kids out with the awareness of why growing food and preserving water is important, then they will combat the problems that the whole is facing world regarding food and water shortages.

Developing of Ideas for Problems to Solve Using Technology

Finding a problem to focus on using technology was not easy. The team chose to focus on the following targets Educational Gaps, Food Scarcity, and Water Scarcity. The targets were established through brainstorming ideas at the start of the competition. Two of the members suggested creating simple and inexpensive hydroponic that people who did not have the money for food would have access to their own food at a lower cost. Another member suggested looking at how we could help with the water scarcity problem in not only New Mexico but many of the Western States. Another idea was to create a better system to secure schools from school shootings. The team took these ideas and brainstormed on how to solve them. In the end, the team voted against working on a school security system because we felt the problem would be too stressful for the team members to investigate as shootings could happen in our school. As we could not settle on one of the other suggestions, we combined both food and water scarcity. The problem and eventual solution is contained under Topic 5 of the Safeguarding Food, Water, and Energy collaboration between NMPED and LANL STEM Challenge. The idea to use the greenhouse at our school to create a Credegree Program and teach students how to grow food was established.

Establishing a Focus for R.I.S.T.

The project started by splitting into groups under a specific field of expertise. The leads were determined by individual skills. Leads were Tori-Anne Platero as White Paper Editor/CAD-SketchUp/Mathematical Model/Co-Orator, Zebadiah Medina as EDP Task Facilitator/Co-Orator, Morgan Oldroyd as Researcher/Outreach, Natasha Gonzales as Pitch Deck/Illustrator, Sydney Babcock as Secretary/Marketing Designer, Iyn Blacksten as Greenhouse/ Water Engineer, Manuel Cortez as Computer Programmer/Prototype Aide, and Luisa Herrera as Public Relations. Four of our team members went to the two local elementary schools to teach lessons on plant science and growing food. These lesson plans were to serve as the start a career pathway in Biosphere Engineering early. Each lesson followed a similar course and coordinated with the lesson plans guided by the NM STEM Ready! and the Next Generation Science Standards (NGSS).[1] The students were asked "Where does your food come from?"; leading them to the correct answer that all food comes from a seed and we went over the cycle of a plant. With this knowledge students learned how to grow their own food by germinating seeds that would be placed into terrariums the following week. The team also worked with fourth graders who planted herbs in pre-made newspaper planters. The plants would be sent to the high school greenhouse and would be tended to by FFA students until December 20th, Winter Break. The 5th grade program consisted of teaching students how to compost food scraps. The 6th grade learned how greenhouses trap heat, and how the trapped head effects greenhouse efficiency.

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[1] 1-LS1-1, 2-LS4-1, 3-LS3-1, 4-LS1-1, 5-LS2-1, MS-ESS2-6, MS-LS2-1, MS-LS2-1 from the Next Generation Science Standards: For States, by States, Vol I

Team Complications

One of the most significant challenges the team faced was the loss of a team member. Extenuating circumstances caused the Communication lead to leave the team. Luisa made valuable contributions to the team all-around, keeping us connected with important individuals involved in the STEM Challenge, and with our project. The remaining seven team members were all reassigned roles to fill the gap her absence made, and fill roles that were not assigned previously.

Building Up the Greenhouse

The STEM project began with the idea of showing students how to grow food and do so in a way that conserved water. The team expanded upon this idea by utilizing the high school's greenhouse. The greenhouse was previously underutilized and in a state of disrepair. Deciding to use this as a basis for our model, we began working out the most energy-efficient design of our project. Our decisions included software, functionality, and what would go into the greenhouse based on the needs established by the group. The head contributors to the greenhouse were Zebadiah Medina, Manuel Cortez, Luisa Herrera, and Iyn Blacksten. These four figured out the irrigation system, the Wadsworth Climate Control Panel, and the mechanism and arrangement of the greenhouse. The engineering team also collaborated with FFA and the students who are in charge of maintaining the greenhouse. It was through the team's actions we developed our official contest prototype, the "Automated Climate Temperature Sensor", to monitor the functionalities of the greenhouse and improve its overall efficiency and usability. The engineering team created a drip system to reduce the amount of water used for the plants, and a hydroponics system for later use. The Heat Efficiency Equation (How to Size a Greenhouse

Heating System, 2014) was used to find out what was the most efficient heater to use in order to keep the greenhouse at 24 Degrees Celsius (75 Degrees Fahrenheit) during the year. The team prepared lettuce plants received from A'viands Food Service Director through the school cafeteria, hooked up the humidity monitor, solved a problem with the greenhouse ventilation system, and the possibility of storing the information from the A.C.T.S. on a remote computer system. Discussions the team had in regards to the greenhouse included how to utilize the space in the most efficient manner and conserve as much water as possible.

A.C.T.S- Automated Climate Temperature Sensor

When working in the greenhouse the engineering team decided that a method for monitoring the conditions in the greenhouse was needed so the engineering team could better understand the conditions inside the greenhouse. Obtaining the data and understanding the conditions would allow us to make the greenhouse energy efficient. After brainstorming, the engineering team decided five sensors would be needed for the model. The sensors were air temperature, humidity, light, CO_2, and soil temperature. The sensors run off an Arduino Nano and an Arduino Mega. The Arduinos allow the team to program the sensors and collect data. Two display screens were needed to show the data in real-time. All components were housed in a water-tight container. As designs were constructed and reconstructed, the light and soil temperature sensors were omitted from the design. The first prototype contained a temperature, humidity, and a CO_2 sensor, the Arduinos, two LCD display screens, and a circuit board to make the system permanent. It is important to note while building the model, safety precautions as dictated by our school's shop safety manual were followed.[2] After a few tests the engineering team noticed that the CO_2

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[2] The name of the shop safety manual was "RHS Wood Shop Safety Program" and it was observed by our shop teacher, Mr. Daniel

display board needed to be reset often as current CO_2 levels were not being displayed. Three ideas for the display problems were a problem with the coding; a problem with the Arduino Nano running the CO_2 sensor and display programming; or a defect in the Arduino Nano. To test for the problem the engineering team decided to purchase a new Arduino Nano and replace the existing Arduino in the system. After troubleshooting, the problem was an issue with the display board. The defective display board has not been changed as that modification will come in a later version of the system. Version 1.2 of the Arduino included the same temperature, humidity, and CO_2 sensor, LCD display boards, the Arduino Mega, and a new Arduino Nano. At this point, the engineering team decided that system needed to relay data to a computer and that would be converted into a graph. Python Code was written to take serial data from the Arduinos and print the data on a text document that could then be input into a graph. From there the system was placed in the greenhouse and connected to a computer housed in the agricultural shop. This new addition allows the data from the greenhouse to be collected automatically and the climate to be monitored at any hour of any day. After four days of testing Version 1.2 was found to be working effectively.

Water Conservation and Insecurity

Water Conservation is one of the most forefront movements in the Southwest United States. In New Mexico, specifically, water conservation is a crucial topic due to the quickly dwindling supply of water in New Mexico. According to evidence, there are even parts of New Mexico that have no access to safe water at all, which is highlighted in Albuquerque Journal's Article "New Mexico is Running out of Water" (Hecht, 2019), while other parts use more than

3.4 Billion Gallons[3] a day. (2015 New Mexico Progress Report, 2015) As a result of New Mexico's inefficient water usage, actions were taken against wasting water across New Mexico. The most notable action is the House Bill 546, which dictates "produced water" recovered from oil and gas production would be treated and reused for New Mexico's needs. Recovered water presents a complex problem, as regulations on "produced water" have not yet been addressed. New Mexico, for all its efforts on conserving water, started to focus on the quality of the "produced water" only recently. As land and sub-terranean areas are used for drilling and fracking, water is not replenished or have time to rejuvenate on its own. Meanwhile, water quality and chemicals put into "produced water" in the "re-treating" process are not heavily regulated. Agriculture and drilling are a way of life in New Mexico, and because of that, water conservation is paramount. Out of New Mexico's $86.5 billion gross state product (GSP) for agriculture and drilling, agriculture accounted for $10.6 billion (roughly 12.3%). (Diemer, Crawford, & Patrick, 2014) Trying to re-use water that was previously discarded is a great move, but ensuring the produced water will be safe to use and is actually efficient to re-use is even more important. Even with those issues stated, it is still both amazing and an acknowledgment of the water scarcity issue that this bill has gone through legislation. The movement to try and limit, or at least change the outdated uses of water in New Mexico is an important one. Water scarcity in New Mexico is an issue the team wants to educate young students about so they can see how the decisions we make today effect the future. While New Mexico experiences drought conditions and worries about water storage, it is not alone because the United States uses over 321.61 billion gallons of water in the course of one day and is not producing enough water to

[3] 3.4 Billion was cited instead of 3.4 Trillion, as stated in "2015 New Mexico Progress Report" due to the data from the USGS, where the number was cited from, stating 3.4 Billion and not 3.4 Trillion

replenish what is used. Around 120 billion gallons of the water used were used for irrigation and livestock and 54 billion gallons used for commercial applications. Not only that, but Arizona, California, Nebraska, and Colorado are also struggling with water scarcity with each of the states trying to present their own solutions for water conservation before they run out. (Holden, 2019) Even without these five states in mind, there are still eleven states with 20-40 percent water withdrawn and twenty-one other states who have at least 10-20 percent. (New Mexico faces the highest water pressures, followed by California, Arizona, Colorado and Nebraska., 2019) Across history, the availability of water has decided not only the quality of life but political status and the restless nature of people. Over 329 Million people depend on water availability in the United States. These numbers represent more than figures on a graph or parts of an article but are actual living people. If the United States does not focus on water conservation or teach students how to not only conserve water but why water should be conserved, then the water scarcity problem will continue to escalate. The epidemic starts in New Mexico, but as research from around the world has shown, it will not stay there. An area effected greatly by water scarcity is the Middle East where countries are suffering from the lack of water. Their governments and political topics focus on water conservation constantly because of the important role water has in the life of those countries. “Water has always been an important resource in the Middle East -- for its relative scarcity rather than its abundance. Disputes over rights to water (for example, building a dam in one country upstream from another) are a fundamental part of the political relationships in the region. Water for irrigation is necessary for many of the ecosystems to sustain crops.” (What role have natural resources played in the politics and economy of the Middle East?, n.d.) Without a proper plan or interventions, the actions of the people in New Mexico will not solve the water crisis but only continue to exasperate water scarcity. Water scarcity has far reaching effects on irrigation and ultimately the sustainability of crops.

Food Conservation and Insecurity

On top of water conservation and the desperate efforts of the United States' Government to conserve what water the states have, there is the food scarcity epidemic. Studies across the United States have shown "11.1 percent (14.3 million) of U.S. households were food insecure at some time during 2018.", and "6.8 percent (8.7 million) of U.S. households had low food security in 2018" (Coleman-Jensen, Gregory, & Rabbitt, 2018). Along with those studies, there are more specified studies done by the No Kid Hungry foundation that show that "1 in 7 children in the United States lives with hunger.". These alarming statistics show not only do millions of people not know where their next meal will come from but out of those people around half of them are children. Students do not have access to the food they need to function in school, at home, or in their everyday lives. The following statistic is a generalization based off of the No Kid Hungry Foundation; 907 students are in the local School District, which extrapolates to 130 students who experience food insecurity. The truth is an astounding number; According to the Raton Public Schools Business Office, the district has an 83.95 percent (761 students) average of families who qualify for free meals. The reality that a majority of the student population in Raton qualifies for free lunches is what allows every meal to be free, as stated in Section 104(a) of the Health, Hunger Free (What role have natural resources played in the politics and economy of the Middle East?, n.d.) Kids Act of 2010 (HHFKA), under the Community Eligibility Provision (CEP). Raton is considered to be a "Food Desert" because there is no local agriculture to sustain the local population in the event of Raton being without incoming or outgoing traffic. Even Statewide, New Mexico is not the only state with an above average food insecurity rate in the

United States. Evidence also supports Texas, Oklahoma, Arkansas, Louisiana, Mississippi, Alabama, Indiana, Ohio, Kentucky, West Virginia, and North Carolina having food insecurity rates that rival or are on par with those of New Mexico. Twelve states out of Fifty is an alarming statistic, especially considering many of those states have large and ever-increasing populations. Food insecurity is just as important as Water Insecurity, and R.I.S.T aims to teach food insecurity awareness.

Conclusion

With R.I.S.T.'s focus decided, the plan established, and A.C.T.S engineered, a systemic plan was developed. The team created a solution to a National Security Problem; the solution is ongoing and will not end with the New Mexico Governor's STEM Challenge. Plans to further the reach of the greenhouse and establish a Credegree program in Bioscience Engineering does not finish with teaching students. The Credegree program established in the school would give students not only the opportunity to learn but also the means to learn about food and water conservation and all the parts contained in the two crucial topics. The greenhouse and the plan for a Credegree[4] program (Busteed, 2019) would be available to any interested student, offering them a way to reduce costs on college courses and provide them with four years of experience in Biosphere Engineering. This program would be actualized by Santa Fe Community College, who would be offering the coursework. New Mexico State University would further the students' education in Biosphere Engineering. R.I.S.T. also intends to run the greenhouse using solar or wind power to increase the efficiency and decrease the expenditure of local electricity. Using the greenhouse, the team would then work toward supplementing food sources for the cafeteria

[4] The R.I.S.T Team's borrowed name for the credential degree created by the pathway.

through a partnership with A'viands food services. R.I.S.T. will also collaborate with the Master Gardeners through the Colfax County Extension Office to supply starters to the community garden and the Raton Intermediate School Tiger Garden. The team's plan would give students ongoing education about food and water scarcity. Students would transfer their knowledge on food and water scarcity to offer more innovative and lifesaving ideas that would provide a safer world for the next generation.

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Appendix A

Criteria and Constraints for the Raton Innovative STEAM Team's Project

Criteria	Constraints
• Control heat inside of greenhouse climate • Create energy source externally modeling workforce industry skills • Model water efficiency and water quality • Greenhouse data monitoring via python programming • Soil science via composting • Begin culture/pathway from 1-12 using PED NMSTEMReady! Standards and Benchmarks • Collaborating with as many teachers, sponsors, and programs to reach as many students as possible during the contest window • Promoting NMPED, LANL, SFCC/NMSU, and private industry to make Biosphere Engineering the first full accredited Credegree in New Mexico	o Not all schools have a greenhouse; private industry donors would be needed to grow our prototype o Contest timeline will force some theoretical modeling o Qualified instructors will be needed to teach and grow the pathway in New Mexico o Capital or the Money needed to incorporate into the project o NMAA contesting for productivity yields with maximum efficiency in sustainable methods to motivate student participation o Future USDA certification for food produced to be used in cafeterias/community kitchens o Higher Education offering an associate degree to career pathway for high school and a Credegree for biosphere engineering

Figure 1. Source: Raton Innovated STEM Team (R.I.S.T.), using ideas brainstormed by the team at the start of the 2019-2020 New Mexico Governor's STEM Challenge

Appendix B

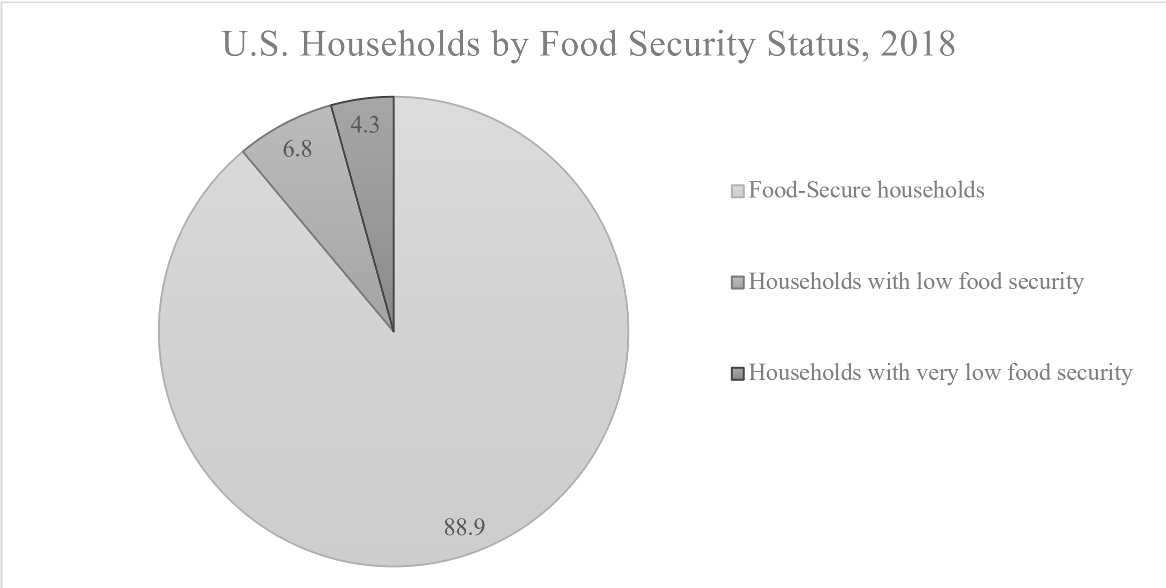

Figure 2. Source: USDA, ECONOMIC RESEARCH SERVICE, using data from the December 2018 Current Population Survey Food Security Supplement

Figure 3. Source: https://www.usgs.gov/media/images/total-water-use-withdrawals-2015

Appendix C
Python Programming for A.C.T.S and Graphing of Data Collected by A.C.T.S.

Arduino Programming:

```
#include "DHT.h"
#include <Wire.h>
#include <LiquidCrystal_I2C.h>

LiquidCrystal_I2C lcd(0x27,20,4);

#define DHTPIN 7     // Digital pin connected to the DHT sensor

#define DHTTYPE DHT11   // DHT 11
//#define DHTTYPE DHT22   // DHT 22  (AM2302), AM2321
//#define DHTTYPE DHT21   // DHT 21 (AM2301)

DHT dht(DHTPIN, DHTTYPE);

void setup() {
  Serial.begin(9600);
  //Serial.println(F("DHTxx test!"));

  dht.begin();
  lcd.init();
}

void loop() {
  // Wait a few seconds between measurements.
  delay(2000);

  // Reading temperature or humidity takes about 250 milliseconds!
  // Sensor readings may also be up to 2 seconds 'old' (its a very slow sensor)
  float h = dht.readHumidity();
  // Read temperature as Celsius (the default)
  float t = dht.readTemperature();
  // Read temperature as Fahrenheit (isFahrenheit = true)
  float f = dht.readTemperature(true);

  // Check if any reads failed and exit early (to try again).
  if (isnan(h) || isnan(t) || isnan(f)) {
    //Serial.println(F("Failed to read from DHT sensor!"));
    return;
  }

  // Compute heat index in Fahrenheit (the default)
  float hif = dht.computeHeatIndex(f, h);
  // Compute heat index in Celsius (isFahreheit = false)
  float hic = dht.computeHeatIndex(t, h, false);

  // Print a message to the LCD.
  lcd.backlight();
  lcd.setCursor(3,1);
  lcd.print("Humidity:  ");
  lcd.print(h);
  lcd.setCursor(0,2);
  lcd.print("Temperature:  ");
```

```
  lcd.print(f);
  //Serial.print(F("Humidity: "));
  Serial.print(h);
  //Serial.print(F("%  Temperature: "));
  //Serial.print(t);
  //Serial.print(F("°C "));
  Serial.print("  ");
  Serial.print(f);
 // Serial.print(F("°F  Heat index: "));
 // Serial.print(hic);
 // Serial.print(F("°C "));
 // Serial.print(hif);
 // Serial.println(F("°F"));
 delay(3600000);
}
```

```
Python Programming:
import serial
import time
from datetime import datetime

#f= open("ledata.txt","w+")

while 1:
	nano = serial.Serial('COM4', 9600, timeout=.1)
	nano.flushInput()
	mega = serial.Serial ('COM5', 9600, timeout=.1)
	mega.flushInput()

	while True:
		data = nano.readline().decode('utf-8')#[:-1]
		#data = nano.readline()#[:-2] #the last bit gets rid of the new-line chars
		if data:

			f=open("co2.txt", "a+")
			now = datetime.now()
			print(data, now )
			date_time = now.strftime("%m/%d/%Y, %H:%M:%S")
			#print(now)
			f.write(date_time)
			f.write("  ")
			f.write(data + '\n')
			f.close()
		data1 = mega.readline().decode('utf-8')
		if data1:
			g=open("temphum.txt", "a+")
			now = datetime.now()
			print (data1, now)
			date_time =now.strftime("%m/%d/%Y, %H:%M:%S")
			g.write(date_time)
			g.write("  ")
			g.write(data1 + '\n')
			g.close()
```

Figure 4. Source: Raton Innovative S.T.E.A.M. Team (R.I.S.T.) Lead Programmer Manuel Cortez and Lead EDP Task Facilitator/Co-Orator, Zebadiah Medina.

R.I.S.T. Budget				
Expenses: Parts		**Quantity**	**$ Actual**	**$ Estimated**
	Arduino Nano	1	8.59	
	Arduino Mega	1	14.99	
	CO2 Sensor	1	57.8	
	Temp/Humidity Sensor	1	6.99	
	Power Cables	1	14.12	
	Arduino Software	1	0	
	Tupperware Container	1	5.99	
	DC Converter 12v to 5v	1	11.59	
	Rechargeable Battery 12v	1	63.99	
	Solar Panel Kit	1	89.95	
	20x4 LCD Display Screen	1	7.98	
	16x2 LCD Display Screen	1	8.99	
	USB Extension Cable	8	35.04	
Total			326.02	
Total Reimbursement			173.98	
Donations to Greenhouse and Teaching				
	Computer	1		516
	Soldering Iron	1		29.97
	Solder	1		13.74
	Wires			
	Hot Glue	1		7.01
	Various Tools			
	Plug Tray Insert	1	1.7	
	Water Pump	1	6.85	
	Rapid Rooter (nutrient)	1	14.77	
	Latch Boxes	3	17.94	
	Root Beer (soda)	2	1.74	
	Dr Thunder (soda)	2	1.74	
	JR Comp Book	4	2.68	
	PH Test	1	4.98	
	Activated Carbon	2	13.04	

	Tank	1	15.87	
	Plant Food	1	8	
	Compost Starter	1	12.99	
	Watering Can	1	5.99	
	Potting Soil	2	14.98	
	AP Soil	1	3.68	
	Foam Board	2	11.96	
Total Donations			705.62	
Projected Greenhouse Instalation fee				
Rimol North Point w/ Polycarbonate		1	12527	
End walls Mechanical Ventilation,	Ridge Vent & Gas Heat			

Figure 5. Source: R.I.S.T. Budget sheet developed by Zebadiah Medina

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Mrs. Medina, RIS Principal
Mrs. Sanchez, Longfellow Elementary Principal

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Mr. Michael Daniel, Woodshop
Mr. Eric Saenz, Ag Teacher/FFA Sponsor

Raton Public School Teachers
Mrs. Mayfield, Yearbook Sponsor
Ms. Fitzgerald, RIS Tiger Garden Sponsor
Mrs. Hephner, RIS 6th grade
Mrs. Martinez, RIS 5th grade
Ms. Main, RIS 4th grade
Ms. Gonzales, RIS 3rd grade
Ms. Lopez, LES 2nd grade
Ms. Boone, LES 1st grade

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