Redefining Science Learning with a Platform for Sharing Experimental Data

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Abstract: This article focuses on integration of the technology of iSENSE into the secondary education as a teaching and learning tool to design, develop, and infuse digital learning experiences that utilize technology. The objective of each lesson was to use this application to achieve redefinition, create new tasks previously inconceivable, and transform the education process using the SAMR model as presented by Dr. Ruben Puentedura. The objective was to create higher-order thinking tasks that have a significant impact on student learning. Data was collected from high school biology, chemistry, and biotechnology classrooms and integrated into lessons using iSENSE, a web based program, created from a collaborative effort of the University of Massachusetts Lowell and Machine Science Inc, for compiling, sharing, visualizing and analyzing data. Through our research, we were able to conclude that the utilization of iSENSE technology helps students manipulate data to gain a deeper understanding of math and science concepts and encourages further research in the 9-12 classroom.

INTRODUCTION

Technology has greatly impacted everything we do, and the world of education has been no exception. The landscape for teaching and learning has changed from the dissemination of information that students can apply to a hypothetical situation, to providing opportunities for students to critically think through authentic tasks and demonstrate mastery in real-world problems. Instruction has thus moved up in Bloom's hierarchy of levels (Adams, 2015).

With its own levels of hierarchy, the use of technology in the classroom has also been improving. The Substitution, Augmentation, Modification, and Redefinition (SAMR) model is a four-level, taxonomy-based approach for selecting, using, and evaluating technology in K-12 settings (Puentedura, 2006). In SAMR, the Substitution and Augmentation levels of the model use technology to replace a traditional method of instruction and/or enhance the learning assignment. Examples at this level may include using a device to type a lab report, or using the spell-check feature of a typing program.

The Modification and Redefinition levels are considered "above the line"—the desired target for instructional reform. by significantly redesigning traditional assignments and/or providing students with a global collaborative experience through the use of iSENSE.The Modification level uses technology to significantly redesign the learning assignment, providing students the opportunity to take their learning experience further. For example, students can embed footage of the lab being completed by recording parts of the experiment to submit with the lab report. In this new assignment, students not only have to communicate their findings about the content of the lab, but they also must demonstrate their understanding of how the lab is completed in order to make a coherent or successful video. Using technology at this modification level encourages a deeper understanding not previously possible.

In the present work, the Redefinition level of the SAMR model is explored using a global collaborative component. In our lab report example, students use technology to collaborate on the analysis of the data collected for the lab. At this Redefinition level, entirely new objectives for an assignment are may be created. In a lab report, students would now be expected to collaborate with peers through technology, and perform analysis of their own data as well as that of their peers. They are now able to identify sources or error or bias, and evaluate data, which may not have been possible without the technology aided design. These kinds of tasks would not be possible without the use of technology within the learning plan.

This paper describes the work of four teachers at suburban high school ("MHS") located in the northeastern region of the United States. This school is currently in its fifth year of successfully implementing a 1:1 iPad program with the entire student body. Most teachers at MHS have successfully incorporated use of the iPads into their respective curricula at the substitution and augmentation levels. Our new challenge is to move our instruction and assessments "above the line" to the transformation levels. We adopted the use of a web-based system called "iSENSE" that allows for sharing and visualizing data. This online tool allows teachers to set up projects containing a curated data set for students to visualize in a variety of ways, including scatter plots, pie charts, bar graphs, and more. However, the truly unique aspect of iSENSE is that projects can also be set up so that students can input their own collected data. This allows for collaboration within a classroom, multiple classrooms within a school, various schools across a district or various districts, and even around the world. This paper describes the within-classroom and across-classroom collaborations we have fostered. With the flexibility to view data in multiple ways, educators can use the power of iSENSE to help students analyze data at a more in-depth level, deepening their understanding not only of the concept being studied, but of data analysis in general.

The paper presents four projects, conducted in multiple subject areas: (1) Investigating the energy content of food (Chemistry), (2) the effect of sugar on pound cake (Chemistry and Culinary Arts), (3) understanding enzyme catalase (Biology), and investigating the carrying capacity of a forest (Ecology).

Project 1: Investigating the Energy Content of Food (Chemistry)

Introduction: During this activity, students "interpreted the results of an experiment in which calorimetry is used to determine the change in enthalpy of a chemical process (heating/cooling, phase transition, or chemical reaction) at constant pressure" [AP Chemistry Learning Objective 5.7].

Methods: The classes spent two days of class time reviewing calorimetry, enthalpy and Hess' Law as well as bond energy. The classes then spent one day conducting their investigation into the energy content of food. Upon completing their investigation students analyzed their data and spent a day practicing free response exam questions released by the College Board that relate to calorimetry.

During the investigation into the energy content of food, students determined the energy content of marshmallows. Using a Vernier temperature probe and Vernier Graphical Analysis data collection Chrome app, students collected a stream of temperature data as the burning marshmallow heated a small can of water. They ignited the marshmallow using a wooden splint. They placed the burning food directly under the center of the can allowing the water to be heated until the food stopped burning. They stirred the water until the temperature stopped rising and allowed the data collection software to collect a final temperature. Students allowed the burned food to cool for about a minute and then found the final mass of the food and food holder. Students downloaded the data from the Vernier Graphical Analysis interface as CSV files and then uploaded their trial data to an iSENSE project entitled "Investigating the Energy Content of Food" (see "Links to iSENSE Projects" at end of paper). By monitoring the temperature of the water, students could then find the amount of heat transferred to it (in kJ), using the formula $q = Cpm\Delta t$ where q is heat, Cp is the specific heat capacity of water, m is the mass of water, and Δt is the change in temperature of the water. Finally, the amount of marshmallow burned was taken into account by calculating the heat per gram of marshmallow consumed in the combustion.

Results and Discussion: Use of the graphical analysis tool allowed for significant modification to a traditional lesson that would involve finding an initial temperature and a final temperature upon the completion of the combustion of the marshmallow. Students were now able to see an obvious, continuous pattern in the temperature of the water over time while the probe collected data every half second.

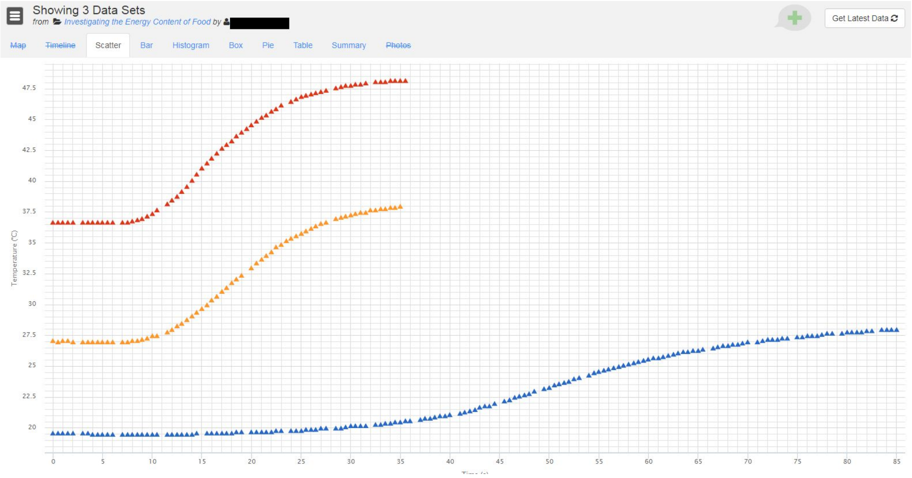


Figure 1: Time series view of water temperature. This is a visualization of all data sets in the iSENSE project. This visualization allowed students in this group to see inconsistencies in their lab performance as they started their data collection much too soon in their first trial.

Although the probes allowed for Modification of the activity, it was not until students uploaded their data files to iSENSE that the lesson was significantly Redefined. Traditionally this lab activity would be centered around manual collection of data and graphing of temperature and time. The use of the probes and iSENSE in this lesson allowed for Substitution, Augmentation, and Modification according to the SAMR model. The lesson is augmented when the students use the same sheets information to graph data since, "augmentation is equivalent to using 'technology to do old things in new ways" (Schrock, 2016). In performing this task during the 2018 school year, most students in the AP Chemistry classes did not have access to the Vernier analysis tools, so they collected data at the start and end of the combustion of the marshmallow. Although this allowed them to calculate the heat transferred during the combustion of the marshmallow, they were unable to see a continuous pattern like the students with access to the probes and the Vernier Graphical Analysis Chrome extension. According to Schrock, "when designing assessments at the modification level one must look at the … online tools that are available" in order to create a "new… learning experience for students supported by the use of technology." The activity was modified as students were given the opportunity to use the Vernier Graphical Analysis platform to collect the temperature of the water over time and then upload the data to iSENSE. In its simplest form, iSENSE allowed for modification of the activity because students used the summary visualization to determine the maximum (final) and minimum temperature (initial) of the water (Schrock, 2016).

The final step of the lab investigation was to analyze the heat loss factors that contributed to the inefficiency of the experiment. iSENSE allowed for the collaboration of all students performing this task. As shown in Figure 1, the iSENSE visualization allowed students in one group to see inconsistencies in their lab performance. iSENSE's ability to allow for easy, collaboration is an important part of this lab activity as the students are expected to perform data analysis and evaluation of evidence. Not only does the College Board expect Advanced Placement students to use data in mathematical relationships, they expect students to be engaged "in a deeper scientific questioning" and "perform data analysis and evaluation of evidence" (College Board, 2014).

Project 2: The Effect of Sugar on Pound Cake (Chemistry and Culinary Arts)

Introduction: Data analysis and interpretation is a skill that often eludes students for various reasons. Students may carry out a lab in which they are able to successfully make observations and perhaps even draw some straightforward conclusions from their observations, but the struggle often comes when they are asked to extrapolate the data they collected to construct explanations for various phenomenon. This is challenging and especially so when the data set they have is small or contains errors.

This lesson was a collaborative effort between culinary arts and chemistry disciplines. In this project, students investigated the chemical and physical properties of sugar that affect the overall quality of pound cake. Students then discussed various visualizations of data contributed by 45 different students in three different classes within their lab groups, as well as contributed to a larger class discussion of data analysis. In addition to the chemistry standard addressed through this lab, the lesson addressed NGSS Science and Engineering Practices.

Methods: In this 4-day lesson, students began by reading an article on the properties of sugar. This assignment utilized the website www.activelylearn.com to bring a traditional reading assignment to the Augmentation level. The website allowed students to identify difficult to understand concepts with the teacher as they were reading, as well as allowing the teacher to oversee each student's progress during reading. Students could define, translate, and hear words, phrases, or entire sentences to aid in their learning. Students then continued on to Day 2 of the lab where they carried out the lab. Each group baked cupcakes with a fixed amount of all ingredients, except for sugar, which differed by group. The varying amounts of sugar included 0g, 200g, 400g (the control), 600g, and 800g. On Day 3, students took the cooled cupcakes and made observations that included color, height, texture, shape, flavor, and overall acceptance. Students then uploaded their data into an iSENSE "Energy Content of Food" project in preparation for the final day of the lesson. On Day 4, students then used the various visualizations available in iSENSE to interpret the data contributed.

Results and Discussion: Students were able to successfully determine a variety of ways that sugar affects the quality of pound cake. Two visualizations which students used to make these determinations are shown Figure 2. First, they were able to confirm the obvious fact that greater amounts of sugar cause a sweeter flavor. They were also able to conclude more complex, and in some cases unexpected results, such that greater amounts of sugar create a dipped shape in the cupcakes, whereas less sugar creates a peaked shape. Interestingly, students had already read about this cause and effect in the day 1 lesson reading assignment. Even with the reading assignment (using technology at the augmentation level) for background content, true understanding of the effect sugar has on pound cake did not occur until the redefinition level of the assignment was reached on day 4 through the use of iSENSE.

Having a much larger sample of data allowed students to view the effects that sugar had on the various cupcake properties. When students selected only their group's data, the data appeared to be inconclusive. The determinations they made would have to be based predominantly on the reading and not on first-hand observations. It would have been difficult if not impossible to determine sources of error as they would not have any other data points to really compare to and their conclusions about the data or about error in the lab would very likely have been incorrect. This has been the case in many labs in the past prior to using iSENSE with my students.

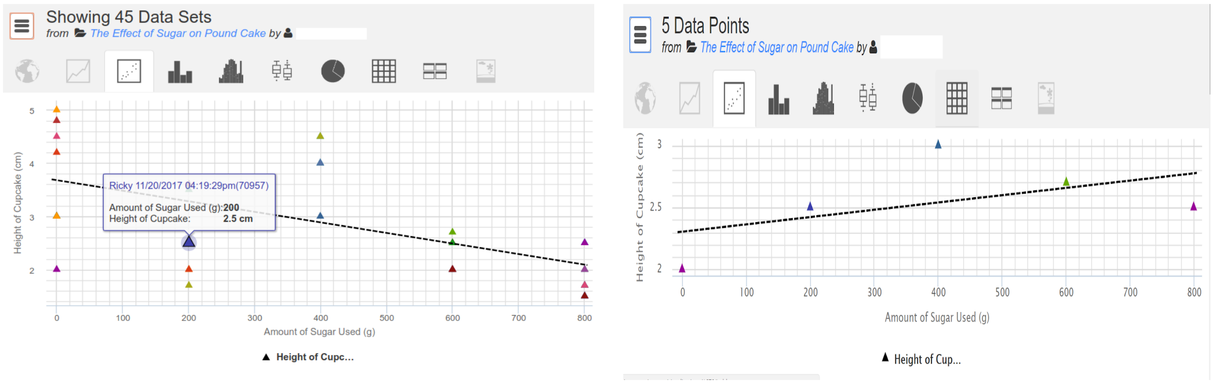


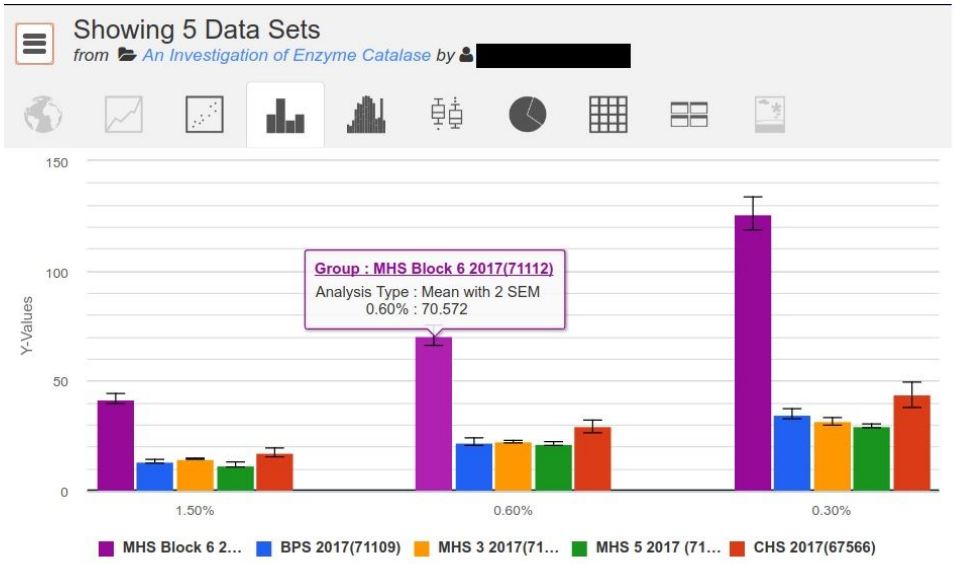
Figure 2: Height of Cupcake vs. Amount of Sugar Used. (Left) 45 data points taken from 3 different classest. The data reflects the correlation between the amount of sugar used and the cupcake height with one of the data ranges (400g of sugar) being an outlier. (Right) 5 data points taken from the same class. It is difficult to tell which points are the outliers and the slope reflected does not accurately show the relationship between the amount of sugar used and the cupcake height.

Project 3: An Investigation in Enzyme Catalase (Biology)

Introduction: Graphs and graph interpretation is an integral part of the AP Biology curriculum. Students are expected to be able to use graphs, analyze data, test hypotheses, and use mathematical modeling to design, develop and implement experiments to support content objectives. The objective of this laboratory exercise was for students to be able to understand the relationship between an enzyme's structure and function, to determine which factors can change the rate of an enzyme reaction, and to determine which factors that affect enzyme activity could be biologically important.

Methods: Students used yeast/sodium alginate spheres to show the rate at which the enzyme in the yeast (a catalase) would break down H_2O_2 into H_2O and O_2 in varying concentrations of hydrogen peroxide (0% hydrogen peroxide, 0.3% hydrogen peroxide, 0.6% hydrogen peroxide and 1.5% hydrogen peroxide). Students created the spheres by mixing 10 ml of each of a 10% yeast (*Saccharomyces cerevisiae*) solution to a very viscous 2% sodium alginate solution. The solution was then drawn up into a 30-ml syringe and dropped, drop by drop, into a 50 ml beaker of 0.15M $CaCl_2$ solution. In doing this, each drop formed an individual yeast "sphere." The spheres remained in the solution for 5 minutes to allow them to harden. Any floating spheres were disposed of and the remaining spheres were drained, rinsed and transferred to a dish of water. A 50 ml graduated cylinder was filled with varying dilutions of hydrogen peroxide starting with a 1.5 % solution, 0.6% solution, 0.3% solution and 0% solution (distilled water). For each solution, students timed how long it took for a sphere to be dropped in, sink and then return to the surface of the liquid. The yeast spheres would sink to the bottom of the graduated cylinder and then, over time, the yeast within the spheres would break hydrogen peroxide down into water and oxygen. The collection of oxygen in the sphere would cause the sphere to rise to the top again. This showed evidence of the reaction taking place. Students repeated this with 10 spheres total in each dilution. Data was recorded in time (seconds) on a data form.

Results and Discussion: Students uploaded their data to iSENSE project "An Investigation of Enzyme Catalase" to graph and view each bar with 2 standard errors of the mean (Figure 3). Data were combined from our MPS district and two other school districts in which the same experiment was conducted (BPS and CPS). The work was conducted in these other districts while being careful to keep all variables constant and modify only the independent variable, thus increase sample size and data validity. With iSENSE technology, students were able to view their data as compared to other class data. The graph below also opened up discussion as to why the MHS block 6 data, although following the trend, was so different. Student were able to correctly deduce that the reaction was faster for this group because the water used to activate the yeast was warmer. Student were able to view the standard error bars and understand that there was a significant difference between the experimental groups as the bars did not overlap.


Showing 5 Data Sets

from An Investigation of Enzyme Catalase by [redacted]

Group : MHS Block 6 2017(71112)

Analysis Type : Mean with 2 SEM

0.60% : 70.572

Figure 3: Enzyme catalase data for all classes individually from 2017–2018 school year. This graph includes data from the same activity run in at three districts: MHS (two groups), BPS, and CPS. The graph shows the time,

in seconds, it took for yeast spheres to break the surface of the hydrogen peroxide in the graduated cylinder, sink and then rise to break the surface again.

Project 4: How Many Squirrels Can an Oak Forest Support? (Environmental Science)

Introduction: Traditionally, the concept of carrying capacity is taught to students by first defining the concept and then providing some examples of what happens when carrying capacity is exceeded. Typically, a line graph display of a population over time is presented, which shows precipitous peaks and valleys as carrying capacity is overshot, the population crashes, and finally species numbers come into balance with the resource environment. This approach provides a basic understanding of the effect that carrying capacity has on a population, but does little to promote student understanding of exactly how a carrying capacity is calculated in the first place. The use of applied technology becomes an obvious choice for helping to fill in some of these intellectual gaps, in order to help students reach a deeper level of understanding of the carrying capacity concept. In this project, the iSENSE technology was used to allow students to share data from across their models, and thereby learn from each others' data.

Methods: Students were expected to answer the "How many squirrels can your oak forest support?" in four major parts. In Part 1, students were asked to create a physical model of an oak forest with five different species of oak trees in three different age classes and canopy sizes. In Part 2, students mathematically calculated their oak forest's average acorn biomass by tree size and by species. They then used these figures to calculate the degree to which their forest can supply the calorie requirements of a typical squirrel. Their final calculation yielded the carrying capacity for their own model forest for the gray squirrel. In Part 3, students were asked to upload their forest specifications and calculated carrying capacity into a shared Google spreadsheet in order to begin comparing forests and results. This step of the lesson involved technology at the Augmentation level, where students checked their own hand-calculations using a formula embedded within the spreadsheet. At this time, students were also introduced to the iSENSE platform in a whole-class discussion format, using a known dataset. Finally, in Part 4, students uploaded their data into an iSENSE project "How Many Squirrels Can YOUR Oak Forest Support." Then they responded to four analysis questions regarding carrying capacity and forest data variables about their own and other students modeled forests.

Results: Students submitted their work in the form of a formal lab report at the conclusion of the project. In general, students enjoyed creating the physical model and were successful at completing the mathematical calculations necessary for determining carrying capacity. More importantly, the use of the iSENSE tool allowed students to visualize multiple data sets, giving context to their own data that would have otherwise been impossible. This aspect of the project reaches "above the line" with reference to the SAMR model, into the Redefinition level. Armed with multiple examples of forest data, students were able to build an understanding of carrying capacity not only on a theoretical level, but sensitivity to how several data variables interact.

Discussion: Students chose a variety of graphics to use as evidence to support their claims regarding carrying capacity. For example, bar charts were overwhelmingly preferred to scatterplots, when in some cases a scatter plot might have been a more effective analysis tool, but since both formats are available in iSENSE, students were able to choose the visualization that was most beneficial to their understandings of the data (Figure 4).

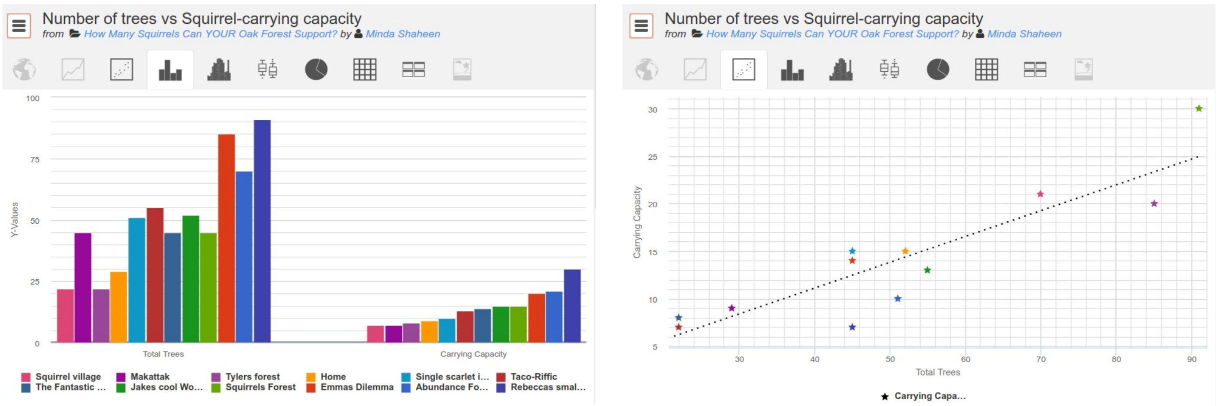


Figure 4: Bar chart and scatter plot visualizations of forest carrying capacity. (Left) Bar charts from left to right show corresponding levels of Total Trees (left set) and Carrying Capacity (right set). (Right) Scatter plot shows relationship between Total Trees (X axis) and Carrying Capacity, with line of regression.

Both of these visualizations encourage students to dig deeper for what else might be influencing the calculated carrying capacity within their forests, when simple numbers of trees is no longer able to fully explain why carrying capacity would differ between forests.

Students gained a solid understanding of both the concept of carrying capacity and the procedure by which it can be calculated for a sample species. But the import of this lesson was extended as students practiced their data analysis and interpretation skills. It is becoming increasingly evident that students can struggle when given problems that have more than one correct answer, that are open-ended, or that rely on interpretation rather than memorized responses. This is where iSENSE helped both students and educators extend the possibilities. Students employed innate levels of curiosity combined with prescribed lesson objectives to achieve new outcomes. iSENSE allowed students to visually compare their results with their classmates, drawing conclusions that helped them interpret the influence of variables on a complex environmental system. This is a key skill in environmental science, and an example of SAMR's Redefinition level, which must be used by students as they move forward with additional complex environmental issues such as urbanization, population growth, and climate change.

CONCLUSION

Using the iSENSE web-based system, four secondary high school teachers took traditional assignments and transformed them to the Redefinition of the SAMR model. Learners have always been able to collect data. iSENSE provided technology that allowed for the creation of new tasks which were previously inconceivable.With this technology, the teachers successfully used iSENSE's ability to share and visualize data for greater student collaboration and student analysis. Each course used iSENSE to meet a different need:

- Using Vernier probeware.
- To complete cross-curricular experimentation (chemistry/food for life)
- To view data in different ways
- To collect and analyze data from different classes in different school districts

Although all of the projects described in this article differ in their disciplinary backgrounds and content objectives, they all have a common thread. Each project uses the analysis of data in multiple ways, and specifically focuses on how students from multiple groups can share and learn from each others' data. In doing so, each project takes instruction and assessment above the line to the Modification and Redefinition levels of the SAMR model. This application helps to make students true 21st century learners with the skills of collaboration, digital literacy, critical thinking and problem solving needed to help students thrive in today's world.

LINKS TO iSENSE PROJECTS

Caitlin Canane October 2017, Investigating Energy Content of Food, *http://isenseproject.org/projects/3321*
Glenda Javier. November 2017, The Effect of Sugar on Pound Cake, *http://isenseproject.org/projects/3343*
Maureen Melanson. October 2017, An Investigation of Enzyme Catalase, *http://isenseproject.org/projects/3205*
Minda Shaheen. October 2017, How Many Squirrels Can YOUR Oak Forest Support? *http://isenseproject.org/projects/3335*

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