Technical Research Report

THE USAGE OF GIZMOS AS A TOOL FOR DEVELOPING NGSS SCIENCE PRACTICES

AN ESSA TIER 3 STUDY OF THE EFFECTIVENESS OF GIZMOS FOR STUDENT SCIENCE ACHIEVEMENT

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EXECUTIVE SUMMARY

The current study looked at whether the usage of Gizmos helps students develop proficiency in the skills that are evaluated in Next Generation Science Standards (NGSS) aligned assessments. Data was drawn from a sample of over 21,000 11th-grade students across 93 urban public high schools in California. Gizmos usage rates over the 2022-2023 school year were compared to the results of the California Science Test (CAST), an NGSS-aligned state science assessment, administered in Spring 2022 and Spring 2023. The study used a correlational methodology, including statistical controls for potential selection bias. The results show that increased usage of Gizmos was significantly related to improved student achievement; schools with higher usage of Gizmos had significantly more students meeting or exceeding science achievement standards compared to schools with lower usage.

Specifically, the key findings include:

- **Students at schools with higher Gizmos usage were 1.3 times more likely to meet or exceed standards on the science assessment than students at schools with lower Gizmos usage.**
- **This difference was found to be statistically significant, even when controlling for the impact of potentially mediating variables such as SES and student-teacher ratio.**
- **A dosage response was also found; greater Gizmos usage was significantly related to higher proportions of students meeting or exceeding standards.**
- **There was no similar relationship found between prior year scores and current Gizmos usage, providing additional support for the hypothesis that Gizmos usage provides students with the relevant practice needed to improve performance on an NGSS-aligned standardized assessment.**

Overall, the current study found that ExploreLearning Gizmos usage was related to significantly higher science achievement as measured by an NGSS state-wide assessment, even when controlling for variables typically associated with statistical sample bias, with exploratory analyses further supporting a causal hypothesis. **This evidence supports the usage of Gizmos as an effective and efficient program that can be used with all levels of learners. Gizmos can help teachers provide the learning experiences needed to support the achievement of proficiency standards on state science assessments.**

This efficacy study was designed to meet the Every Student Success Act (ESSA) Tier 3 (Promising) level of evidence.

INTRODUCTION

ExploreLearning is a recognized leader in the educational software market, creating high-quality solutions for the most challenging problems in K-12 math and science learning. ExploreLearning ***Gizmos*** online simulations bring the power of inquiry-based learning to teachers and students in grades 3–12. *Gizmos* help teachers take advantage of research-proven instructional strategies and enable students of all ability levels to develop conceptual understanding in math and science. With a library of more than 550 academic learning standards-aligned *Gizmos*, teachers can supplement and enhance students' blended learning experiences with interactive visualizations of math and science concepts that are tough to teach and tough to understand.

Each *Gizmo* focuses on a related set of skills or concepts, with multiple lesson activities at varied levels of complexity and depth of content to support scaffolding. In each Gizmos simulation, students can manipulate key variables, generate and test hypotheses, and engage in extensive "what-if" investigations. Students participate in interactive experiments as they explore the concepts behind the phenomena, ultimately coming to understand the deeper underlying concept of a topic and applying it to solving new scenarios and problems.

Additionally, *Gizmos* supports all three dimensions of the Next Generation Science Standards for K–12 Science Education: disciplinary core ideas, crosscutting concepts, and science and engineering practices. These research-based standards were developed to improve science education for all students and set the expectations for what students should know and be able to do. These standards call for students to think and work like scientists and engineers — asking questions and learning through investigation and discovery. Since the release of these standards in 2013, at least 20 U.S. states have fully adopted NGSS standards, and many more have created their own standards using the related NRC framework. Many of these states have also adopted NGSS-aligned assessments which integrate all three dimensions of the standards, to assess both knowledge and skills. ***If students have never engaged in the kinds of practices found in Gizmos, such as developing and using models, they will be underprepared for NGSS-aligned assessments.***

Gizmos inquiry-based approach to learning has been validated by extensive research as a highly effective way to build conceptual understanding in math and science (Cholmsky, 2003). Several independent studies by university-affiliated researchers over the past 15 years have demonstrated the efficacy of Gizmos, with significant positive impacts from Gizmos use in the classroom found on a range of important outcomes including student achievement, classroom engagement, content knowledge, and knowledge application in both math and science (see ExploreLearning, 2023 for a research summary). However, many of these previous studies take a controlled, experimental approach to measuring efficacy, with small

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[1]For additional information on all the ExploreLearning products, please visit https://explorelearning.com/

sample sizes and controlled and contrived learning experiences. ***The current study takes an applied and school-level approach to determine whether the adoption and usage of Gizmos across a school is related to higher student achievement***. The results of the current study help to validate the efficacy of Gizmos in a real-world setting, where adoption and implementation are less controlled and structured, and more impacted by external and environmental factors. The current findings can help administrators and teachers understand the potential of educational technology to serve as a tool for providing students with relevant experiences and practice needed to succeed on skills-based, NGSS-aligned assessments

The current report details the findings from an efficacy analysis of *Gizmos* as a digital complement to the existing science curriculum across nearly 100 urban high schools in California. The goal of the study was to associate Gizmos usage with student achievement in meeting or exceeding grade-level science proficiency standards. The current study does not include an assessment of usage fidelity (i.e. whether teachers are using the program in line with recommended best practices) but looks at how widely across a school the program has been adopted. We also take an exploratory look at other usage metrics, including the extent of product usage across a variety of standards/courses and the frequency of usage by students. The outcome measure being explored is student scores on the California Science Test (CAST), an NGSS-aligned state science achievement test. Here we specifically focus on high school testing, which captures the accumulated effect for these students of usage of Gizmos across both middle and high school years.

This study was designed to meet Every Student Succeeds Act (ESSA) Tier 3 (Promising) levels of evidence according to the U.S. Department of Education guidelines. The study uses a correlational design to look at the statistically significant relationships between the independent variable (Gizmos usage) and the dependent variable (science proficiency), with statistical controls included to account for potential selection bias.

METHODOLOGY

Study Sample

The data for this study came from 93 majority-minority, urban high schools in California, which includes a total testing data of over 21,000 students. Demographic information about the students enrolled in each school was obtained from the NCES Common Core of Data (https://nces.ed.gov/) as well as the state data dashboard. Information presented in this study included student-to-teacher ratio, student racial and ethnic demographics, and a school-level indicator of family socio-economic status.

During the 22-23 school year, secondary science teachers at all 93 schools had access to the Gizmos program. Several schools had access to Gizmos as early as 2015, with all schools gaining access by fall 2021. Professional Development and support were offered to the teachers through the Customer Success team.

Independent Variable: Gizmos usage

Gizmos usage data was aggregated at the school level. **Table 2** describes the three variables calculated and used in the current study. The primary variable for assessing how widely used Gizmos were across a school was calculated by dividing the number of students who accessed Gizmos at least once during the 22-23 academic year by the total number of enrolled students at that school. A median split was also used to group schools into high users (n = 46 schools) and low users (n = 47 schools). **Table 3** includes descriptive information about the high and low using Gizmos schools. Two additional variables were calculated for exploratory analyses looking at usage patterns and standards achievement. The number of distinct Gizmos used by a school provides a measure of how widely used Gizmos are across a school; schools using more distinct Gizmos are likely to incorporate Gizmos across a greater variety of lessons and courses. The third variable, the average number of Gizmos views per student per school, give us insight into the frequency of use among those students who were using Gizmos. These three variables are distinct measures of adoption, which may or may not align with intended pedagogical approaches, but together can give us a high-level view of a school's usage patterns.

Table 2: Gizmos usage variables calculated for the current study

Variable	Calculation	Insights
Proportion of students using Gizmos	The percentage of all enrolled students at the school who accessed Gizmos at least once during the 22-23 academic year	Assess the degree to which a school fully adopts the program for all students; Used to differentiate high vs low using schools
Distinct Gizmos used	The number of distinct Gizmos used by at least one student across the school during the 22-23 academic year	Assess the breadth of Gizmos adoption across different classes, standards, and/or units
Gizmos views per student	The total number of Gizmos views for the entire school divided by the number of students at that school who accessed Gizmos at least once during the 22-23 academic year	A measure of the frequency of usage by active students

Table 3: Descriptive information about schools with high Gizmos usage and schools with low Gizmos usage

	Proportion of students using Gizmos	Gizmos views per student M(SD)	Distinct Gizmos used M(SD)	Student Demographics	Percentage of schools categorized as high-poverty	Student-Teacher Ratio
Low using schools (n = 47)	Mean = 14% Range = 1% - 26.5%	4.31 (2.21)	10.66 (9.74)	80% Hispanic 7% White 4% Asian 8% Black	83%	19.9
High using schools (n = 46)	Mean = 43% Range = 27.4% - 80.2%	6.04 (3.91)	32.50 (29.19)	78% Hispanic 6% White 7% Asian 7% Black	78.3%	20.0

Dependent Variable: NGSS-aligned State Science Test

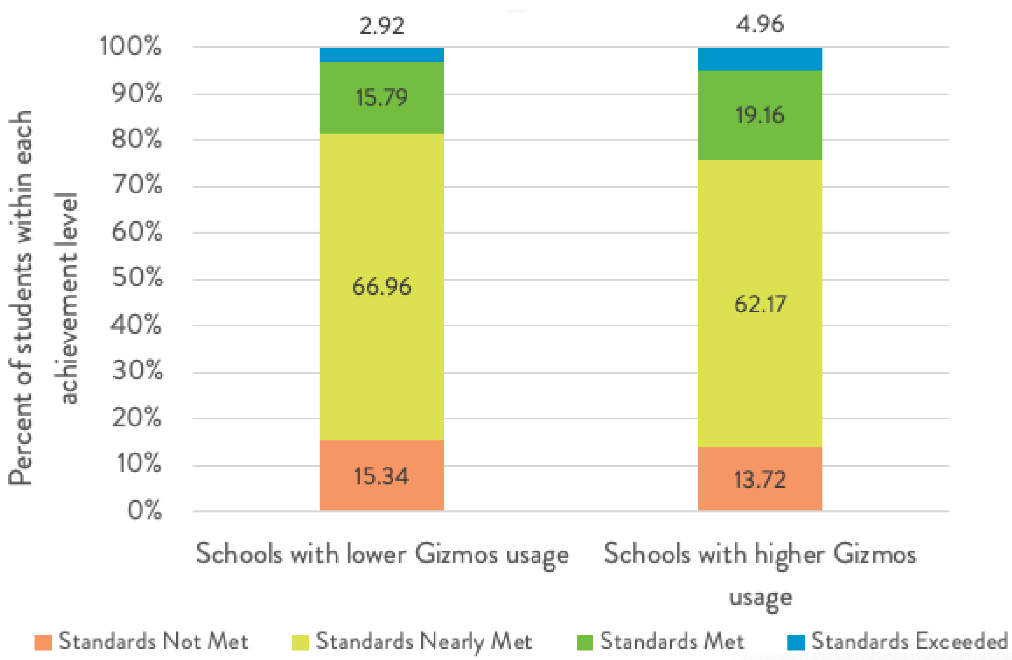
Outcome data was scores on the CAST high school assessments in spring 2023, collected from the state assessment public dashboard. The relevant metric analyzed in this study was the percentage of enrolled students who fell into the Level 3 (Standards Met) or Level 4 (Standards Exceeded) categories. According to the state website, falling into this category indicates that a student shows an understanding of and ability to apply the knowledge and skills that make up the state standards performance expectations.

Planned Analyses

All statistics were performed using SPSS v29. To satisfy promising levels of evidence for ESSA, we planned an analysis that allowed the inclusion of statistical controls for variables related to potential selection bias. One-tailed significance testing was used throughout to test the directional hypothesis that schools with higher Gizmos usage would outperform schools with lower Gizmos usage. A one-way ANCOVA was planned with SES measures and student-teacher ratio used as covariates. Correlational analyses were also planned to test for exploratory relationships between increased usage and increased performance.

RESULTS

In schools with higher Gizmos usage, 24% of students met or exceeded standards on the test, compared to only 18% of students in schools with lower Gizmos usage. A one-way ANCOVA was conducted to test the significant unique impact of Gizmos usage on meeting or exceeding test grade-level standards while statistically controlling for the impact of SES and student-teacher ratio[1]. Even when accounting for covariates, Gizmos usage remained significant [$F(1,93)=3.573$, $p = .031$]. This means that the likelihood of students achieving or exceeding grade-level standards on the 2023 exam can be partially attributed to high or low Gizmos usage during that school year.



To further support the hypothesis that Gizmos usage in 22-23 is driving student learning and improving 2023 spring scores, a similar analysis was run using 2022 exam scores. A significant relationship in this analysis would suggest that teachers with higher achieving students are simply more likely to use Gizmos and would decrease our confidence in a causal relationship of Gizmos usage on student achievement. There was no significant difference in 2022 test scores between the two groups of schools [one-sided t-test on mean scale scores, $t(1,91)=.146$, $p = .442$], providing additional confidence that the relationship between Gizmos usage and test scores reflects a causal impact of program usage.

[1]*Preliminary analyses showed that SES was highly correlated with student race/ethnicity (r's > .7), including the proportion of Asian, White, and Hispanic students. To avoid violating the assumptions for ANCOVA, we focused on SES as the most relevant predictor and included only that variable in the current analysis.*

We also looked at more exploratory relationships between usage patterns and test scores. Pearson's correlations found significant, positive correlations between the percentage of students meeting or exceeding standards at a school and the number of distinct Gizmos used by that school [$r(93) = .307$, $p = .002$] and the average number of views of Gizmos per student [$r(93) = .190$, $p = .034$]. This provides preliminary evidence that different usage and dosage patterns, specifically a greater breadth and depth of usage of Gizmos, are related to test scores, further supporting the hypothesis that Gizmos usage supports science achievement.

CONCLUSIONS

The current study used a correlational method to test the hypothesis that Gizmos usage supports student proficiency on a Next Generation Science Standards (NGSS) aligned state assessment. The NGSS standards call for students to think and work like scientists and engineers — asking questions and learning through investigation and discovery. If students have never engaged in the kinds of practices found in Gizmos and STEM Cases, such as developing and using models, they will be underprepared for these assessments.

Our results showed that across nearly 100 urban high schools in California, students at schools with higher usage of the Gizmos product were more likely to meet or exceed proficiency standards on the state Science Test compared to students at schools with lower usage of Gizmos. This relationship was significant even when controlling for variables typically associated with student achievement, including socioeconomic status and student-teacher ratio. Additional analyses further support our causal hypothesis, including directionality over time and a significant dosage response. These results, with statistical controls for selection bias, meet Promising ESSA Evidence (Tier 3).

The current findings should provide increased confidence to administrators and teachers that Gizmos can be implemented as a tool for providing students with relevant experiences and practice needed to succeed on skills-based, NGSS-aligned assessments.

ABOUT EXPLORELEARNING

ExploreLearning LLC, based in Charlottesville, VA, was founded in 1999 by educators looking for new ways to inspire students across grades K–12 and help them succeed in math and science. With a philosophy of life-long learning driving our thought leadership, a careful attention to the current needs of educators in today's rapidly-shifting educational culture, and a legacy of proven results, ExploreLearning is the best combination of proven expertise and innovative solutions over time to meet today's and tomorrow's educational challenges.

Our four digital programs (Reflex®, Frax®, Science4Us®, and Gizmos®) are currently used in classrooms in every state in the U.S. and more than 80 countries worldwide. Our programs are state- and national-standards aligned, including Next Generation Science Standards (NGSS) and the Standards for Mathematical Practice (SMP). ExploreLearning is a recognized leader in the educational software market, earning many major edtech awards.

We aim to foster student success through the use of galvanizing, age-appropriate multimedia, including interactive simulations, STEM case studies, adaptive games, instructional videos, and much more. Our development team of engineers, researchers, and instructional-design experts, most of whom are former educators, are continually innovating beyond the latest advancements in instructional pedagogy and edtech. Our programs support students in developing mastery of fundamental skills and deep conceptual understanding in math and science, while also fully engaging them in the process of internalized learning, promoting growth mindset, resiliency, productive struggle, and perseverance.

Our goal is to provide educators with captivating, best-in-class digital learning in math and science that helps students reach their full potential. We firmly believe that teachers are mission-critical, i.e., the greatest influence on student success. We also believe that data, instruction, and practice, when operating in tandem, are paramount to improving student learning and academic achievement. In support of these foundational beliefs, we deliver curricula, professional learning, and implementation and technical support services that:

- Combine research-proven instructional methods and innovative technology
- Enable equitable access to math and science learning for all students
- Build strong, lasting foundations for student success by developing procedural and conceptual understanding
- Supplement core curricula with flexible digital and blended implementation
- Create positive outcomes and results for both students and teachers

REFERENCES

Cholmsky, P. (2003). Why Gizmos Work. ExploreLearning. [Research Report] Retrieved from http://www.gizmos.explorelearning.com

ExploreLearning (2023). ExploreLearning Gizmos: The research behind our program. [Research Report] Retrieved from https://gizmos.explorelearning.com/user_area/content_media/raw/GizmosResearchSummary.pdf

RESEARCH REPORT

Gizmos

Gizmos Support Classroom Scientific Sensemaking

Executive Summary

With the wide adoption of new science standards emphasizing scientific sensemaking, engaging and interactive High-Quality Instructional Materials (HQIM) are critical for helping teachers meet modern educational standards, fill gaps in core curriculum, and improve student outcomes in STEM. The current study summarizes responses from nearly 300 teachers on the impact of Gizmos interactive math and science simulations on student engagement and learning in their science classrooms. Teachers reported that Gizmos significantly enhanced student engagement, understanding, and enjoyment in science, outperforming other similar instructional materials. Teachers also noted that Gizmos are a versatile tool supporting online learning, personalized activities, and equitable outcomes for all students.

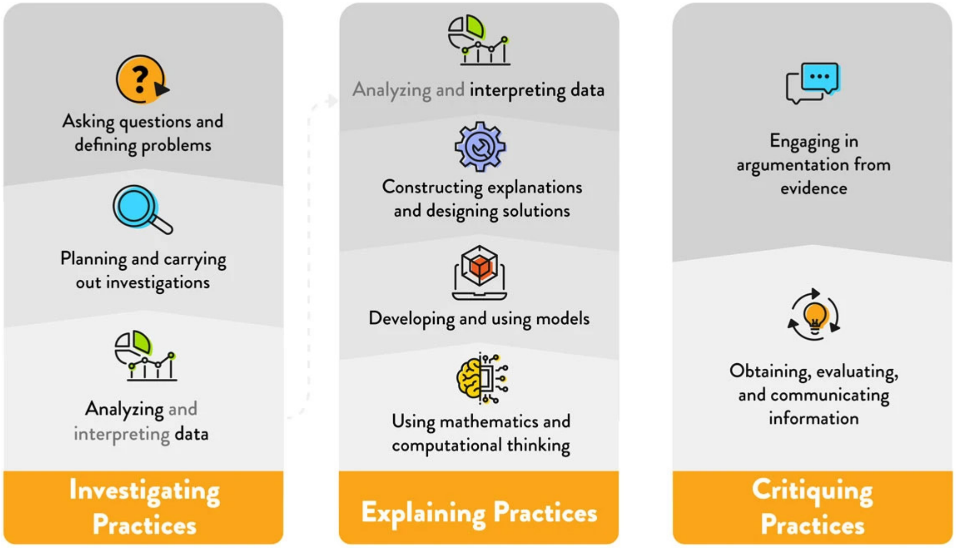
Engaging Minds, Enhancing Knowledge: Insights from Teachers Using Gizmos to Support Scientific Sensemaking

Science classrooms have undergone a major shift in the past ten years. Nearly every U.S. state has adopted new K-12 science standards that emphasize an approach to learning where students actively integrate ***the practices of doing science*** with the ***core ideas of science*** in the context of ***exploring phenomena*** and solving real-world problems. Engagement in the science practices, such as asking questions, developing models, and analyzing data, gives students the opportunity to learn the way scientists do—through active experimentation, exploration, and hands-on inquiry.

> *"Science is an essential tool for solving the greatest problems of our time and understanding the world around us."*
>
> *National Academies of Sciences, Engineering, and Medicine, 2021 report*

Inviting students to participate in this kind of **"scientific sensemaking"** has been shown to be the most effective way to deepen students' understanding, help them build connections across science disciplines, and prepare them to think critically and solve novel problems, a skill set increasingly in demand in today's workforce. Research with adopters of new K-12 science standards that encourage scientific sensemaking found increased student engagement, deeper student learning, and better outcomes even for low-performing and at-risk students (WestEd, 2020).

Science and Engineering Sensemaking Practices



High-Quality Instructional Materials (HQIM) are essential for enhancing both instructional effectiveness and efficiency to support teachers in meeting and these challenging new standards and fostering students' sensemaking. HQIM also need to be accessible to all students, including English language learners, students with disabilities, and those from diverse cultural and socioeconomic backgrounds. Lastly, HQIM include assessments that align with the new standards, enabling teachers to track student progress in both knowledge and practices in preparation for state assessments that evaluate the same.

High-Quality Instructional Materials have been increasingly recognized as an important factor in improving educational outcomes. A number of research studies over the last few years have found significant impacts on student learning outcomes as a result of adopting high-quality curriculum materials (see Steiner et al. 2018 for review). These studies suggest that "**switching from a low- to a high-quality [resource] can boost student achievement more than other, more popular interventions** such as expanding preschool programs, decreasing class sizes, or offering merit pay to teachers" (pg. 9), leading to the conclusion that adopting HQIM can be one of the most cost-effective school improvement tools.

Lack of Truly Aligned Instructional Materials

Although standards-aligned instructional materials are now available for adoption, district leaders indicated that **most materials, if not all, have gaps**. It is unlikely that any instructional materials will be a perfect fit for any district. Even if a district has adopted instructional materials for science, the district should not consider new standards implementation a done deal.

WestED, 2020 report

Unfortunately, few K-12 science curricula meet the bar of HQIM and fully address all of the complexities of the new standards. A recent analysis from EdReports highlights the need for more HQIM in K-12 science. While the report found that 96% of science teachers said that materials aligned to their state's science standards are critically important to them, only 37% of those teachers found their current materials to meet the criteria for HQIM.

A further analysis of the materials teachers actually have available to use found that **just 6% of science teachers regularly use HQIM** (EdReports, 2024). Thus, the availability of High-Quality Instructional Materials that teachers are willing to use is a **critical need** for supporting both teachers and their students.

To meet this need for more HQIM for science instruction, the **ExploreLearning team designed Gizmos**. The Gizmos resources include both Gizmos simulations, interactive math and science inquiry-based activities for grades 3-12, Gizmos STEM Cases, case studies that put students in the role of STEM professionals tasked with solving real-world problems, along with customizable worksheets to help teachers and students dive even deeper into the problems.

ExploreLearning designed these resources as supplementary HQIM learning materials. Gizmos are intended to integrate with and amp up the focus on science sensemaking of any core curriculum, and be easy to use and implement for both teachers and students. They can also be used for remediation around science sensemaking. The ExploreLearning team was eager to document just how well teachers found Gizmos resources to meet this challenging but important goal.

Researchers conducted the current study to provide a window into teachers' experiences using the Gizmos products and materials to engage their students in inquiry-based learning activities that meet the newest standards and to ascertain what kind of student outcomes are achieved as a result. ExploreLearning designed Gizmos as supplementary HQIM learning materials to integrate with and emphasize the science sensemaking of any core curriculum. Gizmos virtual simulations are easy to use and implement for both teachers and students. Discover how teachers found Gizmos resources to meet challenging but important classroom goals.

The team conducted an online survey of math and science K-12 teachers who used either Gizmos simulations or Gizmos STEM Cases (*referred to collectively here as Gizmos*) during the 2023–2024 school year from three different school districts in the US and Canada. A total of 298 teachers completed the survey, which included both rating scale and open-ended questions. Most teachers used the learning materials frequently, with over half of the teachers (58%) using Gizmos simulations at least once per month, and 31% of Gizmos STEM Case users using them at least once per month. Some of the topics that were addressed in the survey and summarized here are:

- ***The ways that Gizmos support the needs of the 21st-century classroom***
- ***Using Gizmos to engage students in science sensemaking practices***
- ***Positive student outcomes observed from using Gizmos***

Meeting the Needs of the 21st Century Classroom

Teachers were asked about the ways that Gizmos were particularly impactful in their classrooms. **A number of these comments highlighted the ways that Gizmos serve as a versatile and valuable tool to support the needs of the 21st-century science classroom**. From online learning to supplementing physical labs and ensuring that all students, regardless of their background or learning challenges, have an opportunity to succeed, teachers told us of the many ways that Gizmos uniquely supported their needs.

1. Support Online or Blended Learning Strategies

Gizmos were invaluable in a rapid switch to online learning environments, where students needed to engage with science content remotely or asynchronously. Teachers noted how Gizmos allowed them to deliver meaningful, interactive, and engaging lessons in the absence of traditional in-person labs, without sacrificing the “hands-on” aspect of inquiry-based learning.

- *"During the pandemic, students were able to see concepts online that I was not able to demonstrate in person. It made all the difference between theory and practice where students could fully understand the concepts."*

- *"As an online teacher, we don't have a lab in our school, or any science equipment, so having online labs at our disposal is incredibly useful!"*

- *"Gizmos allowed my online science class to practice lab exercises in the most realistic way possible in a virtual class environment."*

2. Provide Flexibility in Assigning and Personalizing Activities

Another way that Gizmos simulations meet today’s teaching needs is the flexibility they provide to teachers in terms of assigning activities and adapting them to individual student needs. Teachers appreciated the ability to assign Gizmos as either homework, makeup work, or alternative assignments for students who needed extra time or who were unable to attend class in person. The customizable nature of the activities also made it easy for teachers to align the content with their own teaching objectives or specific student needs, enhancing their teaching strategies. This ability to tailor assignments helped both teachers and students navigate the complexities of different learning paces and circumstances.

- *"The worksheet + teacher answers were so helpful for me to edit for my purpose—having a ready-to-go resource is so helpful."*

- *“Students who do independent credits/credit recovery usually request Gizmo activities as a substitution for other packaged materials”*

Several educators highlighted the convenience of using Gizmos for students who were still learning remotely due to health issues or other circumstances that kept them out of the classroom. For example, one teacher mentioned using Gizmos for a student with severe health concerns, allowing her to achieve course expectations on her own time.

3. Complements to Primary or Physical Lab Resources

Most teachers in the survey (89%) reported using Gizmos as a substitute for a laboratory activity. Gizmos were frequently noted as a solution to the challenge of limited physical lab resources. Teachers in schools with restricted budgets or inadequate lab space found that Gizmos provided a meaningful (and cost-effective) way for students to engage in science experiments. This was particularly useful for experiments that required expensive or hard-to-find materials, tools, or lab setups that were not available in the classroom. **The ability to replicate lab experiences with interactive, digital tools allowed students to conduct experiments that might otherwise have been impossible**.

For example, one teacher mentioned that Gizmos were essential in helping students experiment with acids and bases when the school lacked litmus paper and other necessary lab materials. Another teacher emphasized how the **Frog Dissection Gizmo** served as an excellent supplement when behavioral challenges with her students made her nervous about diving right into a physical dissection.

- *"I used the **Melting Points Gizmo** to accompany a lab I did in the classroom. It was great as the Gizmo allowed students to see ionic substances melt, which we could not do in our lab due to limitations."*

- *“This year, I was moved from a science classroom to a cart for a push-in. I went from having a lab classroom to having no space. Gizmos were really helpful this year to explain phenomena.”*

4. Ensures Equitable Learning Outcomes for Students

Gizmos were highlighted as an important tool in supporting equitable learning outcomes for diverse student populations, including English Language Learners (ELLs) or Multilingual Learners (MLLs), students with learning disabilities, and students who face behavioral challenges. Teachers noted that the opportunity to work at their own pace with instant feedback helped these students better understand challenging content and build confidence.

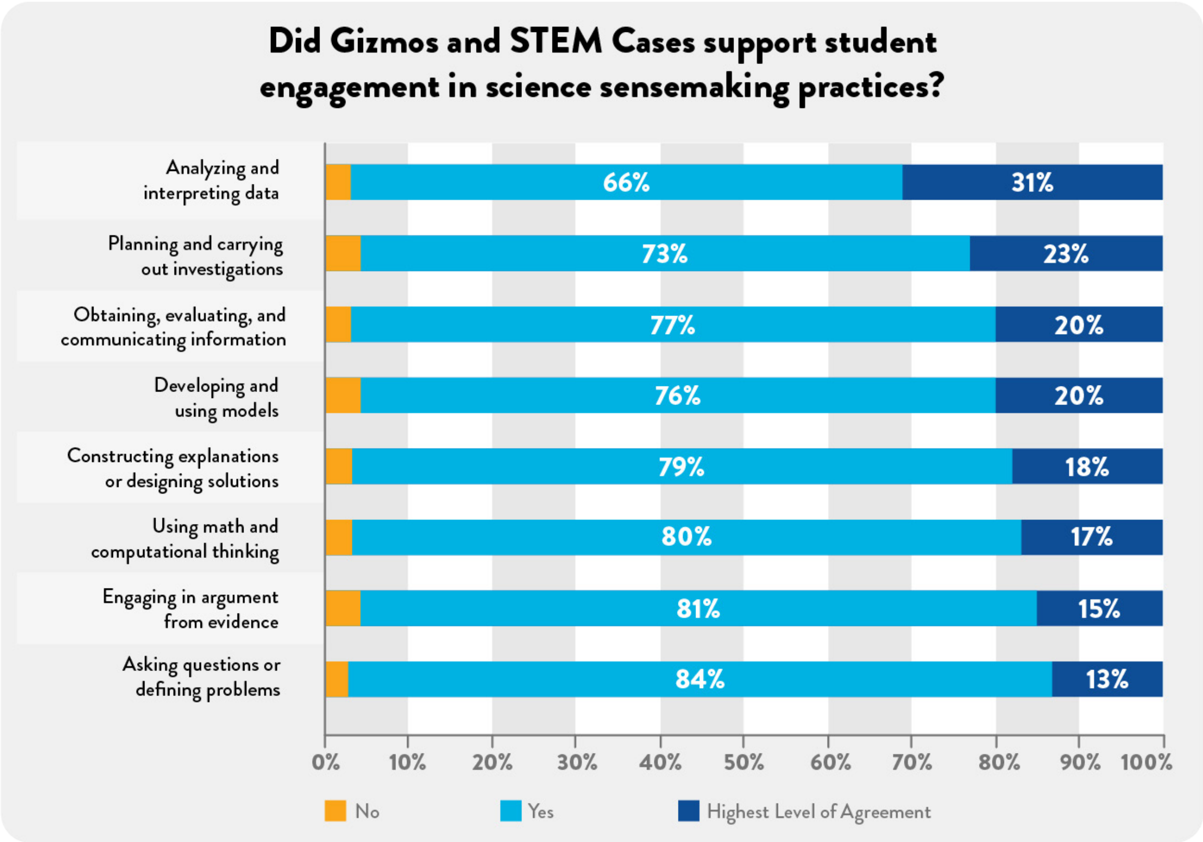
For example, teachers working with MLL students reported that the **visual and interactive elements of Gizmos helped students grasp difficult concepts more effectively, reducing language barriers and enhancing comprehension**. For students with other challenges, Gizmos provided a less intimidating, self-paced way to explore scientific phenomena, which contributed to better engagement and deeper learning.

- *"Gizmos helped my students understand measurement on a deeper level using the modeling tools. This was particularly beneficial for my MLL students."*
- *“A student in my physics class generally had difficulty following concepts during lecture or even while reading the textbook. However, she often would say ‘I get it now’ after completing Gizmos assignments.”*
- *“A student in my class who consistently struggles with maintaining focus told me during the Programmable Rover Gizmo that it was the best day of science they ever had and they loved it. They not only were focused for the entire time but were excited to answer the questions.”*

Using Gizmos to Engage Students in the Science Sensemaking Practices

To look for evidence that products were delivering on their original value proposition, teachers were asked whether Gizmos supported their students’ engagement in each of the eight science and engineering scientific sensemaking practices, and if so, to what extent on a 4-point scale (little - considerable).

Over 95% of teachers responded that these tools did support student engagement for each of the practices. Many of these responses indicated that they felt Gizmos and STEM Cases provided “considerable” support for engaging in the practices, particularly the practices of *“Analyzing and Interpreting Data” and “Planning and Carrying Out Investigations.”*



This can also be highlighted in the many quotes from teachers responding to the question of impactful Gizmos and STEM Cases usage, which cited many of the practices:

- *"Students used the **Heredity and Traits STEM Case**. They were able to see how the behavior of bees resulted from inherited traits and how bees continued to protect the gene pool. Students were able to apply this to human reproduction and heredity and gain a better understanding of the concepts we explored in class. They were able to discuss what they learned and explain traits/heredity using the information from the STEM Case."*

- *"I used the **Flood and Storm-Proof Homes Gizmo** during our extreme weather unit…Students saw from a structural engineering point of view why the foundation was so important, and the students were able to see the strength of weather. It was just a very memorable fun lesson and the kids loved playing around with the different building options. We tried to see whose house could withstand the flood for the least amount of money, with the least amount of upgrades, etc. so it turned into so much more than just building a little house in a flood."*

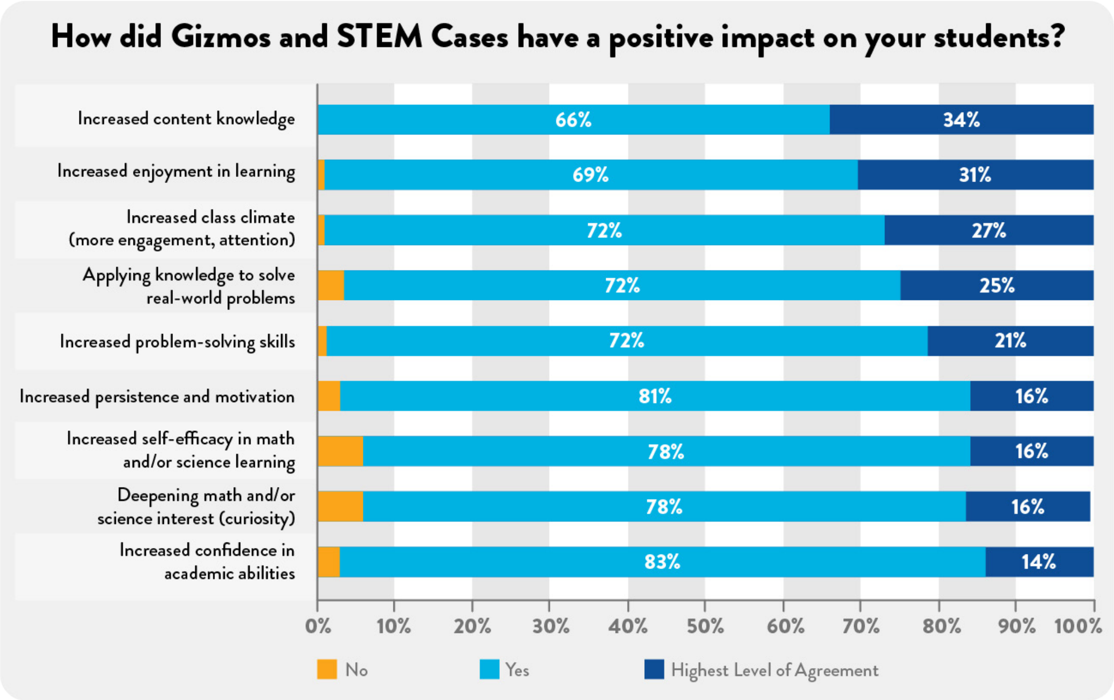
- *"This year, my students had difficulty understanding the connection between photosynthesis and cellular respiration. In doing the **Cell Energy Cycle Gizmo** they were able to play with the amount of waste product each cycle produced in order to make a relationship between the two cycles."*

Student Outcomes from Gizmos and STEM Cases

We were also interested in documenting the student outcomes observed by these teachers after using Gizmos and STEM Cases. For instance, did students improve their content knowledge, problem-solving skills, and application of knowledge to other phenomena? While knowledge is an important outcome, how students feel about learning is also an important outcome that can have a large impact on their future trajectory in STEM courses and STEM careers, but is far less frequently quantified by formal classroom assessments.

Overall, nearly all (93%) of teachers surveyed said that they observed a positive impact of Gizmos on their students, with 42% observing moderate outcomes and 51% observing considerable improvements. This level of learning and engagement observed from Gizmos was an improvement from other HQIM materials they have used to teach similar concepts. **81% of teachers surveyed said that Gizmos were better at improving learning and engagement than any other materials they had used.**

We also asked teachers about the specific outcomes that they observed from student usage of Gizmos, including questions about improved knowledge, improved attitudes toward learning, and problem-solving skills. Over 94% of teachers responded that these materials had a positive impact on students for each one of the outcomes assessed. Many of these responses indicated that they felt Gizmos had "considerable" positive impacts, particularly in the areas of increased content knowledge, application of knowledge to other phenomena, increased class engagement and attention, and increased enjoyment in learning.



These same findings can also be seen in the teacher-provided stories of using Gizmos in ways that resulted in positive impacts on student knowledge and affect:

- *"The **Photosynthesis Lab Gizmo** that uses different colors of light to demonstrate the rate of photosynthesis is always an 'a-ha' moment for students. When they get into the Gizmo and start to realize how all the factors that affect photosynthesis work together, it makes the concept really click for the students."*

- *"[My students] work very well when we work with hands-on concrete examples. Working together through the **Ecosystems STEM Case** we were able to explore how populations grow, shrink, and change. They were able to then take that knowledge and apply it to a novel task where they had to analyze the human population of earth and say how we could change that population to make better use of our resources."*

- *"My grade 5 students were struggling with understanding decimal numbers and developing negative feelings about the learning. I introduced them to the **Treasure Hunter Gizmo** where they needed to use decimal numbers to find the treasure, and every student was engaged and demonstrating increasing understanding to complete their missions."*

- *"The **Summer and Winter Gizmo** is a great tool for students to understand why it is colder in the winter and hotter in the summer. It integrates some Optics prelude for the next grade and debunks the myth that the Earth is further from the Sun in the winter!"*

- *"Students enjoy ALL the Gizmos. The students particularly enjoyed the **Frog Dissection Gizmo**. As a teacher it was the next best option to an actual dissection."*

Feedback from real teachers and classrooms underscores the impact of Gizmos on increasing students' understanding and overall engagement with science. Gizmos are High-Quality Instructional Materials that enhance and support scientific sensemaking for all students.

SPOTLIGHT ON CLASSROOM SUCCESS

We asked teachers to share notable success stories they observed this year.

"I had a student who was struggling to motivate himself to learn about ecology. However, he did like to fish. I assigned him the Pond Ecosystem Gizmo and our ensuing discussions allowed him to pass the unit."

"Gizmos transformed my 9th-grade biology class, making complex concepts accessible and engaging. Traditionally, students struggled with the intricacies of [cellular respiration], finding it abstract and confusing. Gizmos provided a game-changer. Students could better visualize the stages of cellular respiration in real time. They manipulated variables, observed outcomes, and engaged in trial-and-error learning, which deepened their understanding far beyond textbook explanations."

"One student, who had consistently struggled with science, had an 'Aha!' moment. She exclaimed, 'I finally get it!' Her newfound confidence spread throughout the class, fostering a collaborative environment where students eagerly discussed their discoveries and hypotheses."

"I teach 'Interactions in Ecosystems' and it can be very difficult for some students to create a visual story in their mind about how one species can impact another. Since it is very difficult to create this situation in reality, having the simulations run through Gizmos is a lifesaver. Students can alter the populations and add other factors and see what happens over the simulation."

"My students absolutely loved solving the Cell Respiration STEM Case of the CIA agent being poisoned and they had to figure out which toxin caused it. They used their knowledge of cellular respiration to solve the problem. They felt important and they were doing 'real' science work solving the case."

"One of my students struggled with math and found it unengaging. Initially skeptical, she tried a Gizmo on quadratic equations. Manipulating variables and seeing immediate graph changes helped her understand the concept better than traditional methods. She continued using Gizmos throughout the semester. While some topics remained challenging, the visual and exploratory approach made them more approachable. Her participation noticeably increased with Gizmos compared to traditional methods. By the end of the semester, she felt more comfortable with math."

"Recently a student who is reluctant to do a lot of work was able to demonstrate his incredible understanding of how the Fast Plants®- Growth and Genetics Gizmo enabled him to manipulate the outcome of the plants grown. He was then able to be the expert for one of his peers, improving his self-confidence."

"The STEM Cases are amazing. The design exposes students to actual problems and the scientific processes used to solve them. They connect well to the topics being studied. The Cases generate discussion among the students. They also expose students to ways in which the material they are studying is applicable in the real world and how this knowledge can be used in science careers."

"I used the Density Gizmo with students as an inquiry activity which was followed by a hands-on lab to determine the identity of a metal density. Students had a better understanding of what to do as they were able to use what they learned in the simulations."

CITATIONS

EdReports (2021). Data Snapshot: K–12 Science Materials. Retrieved from https://edreports.org/resources/article/data-snapshot-k-12-science-instructional-materials

EdReports (2022). 2022 Data Snapshot: K–12 Science Intructional Materials. Retrieved from https://edreports.org/resources/article/data-snapshot-k-12-science-instructional-materials-2022

EdReports (2024). State of the Instructional Materials Market: The Availability and Use of Aligned Instructional Materials in 2023. Retrieved from https://www.edreports.org/resources/article/state-of-the-instructional-materials-market-2023

National Academies of Sciences, Engineering, and Medicine. (2021). Call to Action for Science Education: Building Opportunity for the Future. Washington, DC: The National Academies Press. https://doi.org/10.17226/26152.

Steiner, D., Magee, J., Jensen, B., & Button, J. (2018). What we teach matters: How quality curriculum improves student outcomes. Johns Hopkins Institute for Education Policy and Learning. First. Retrieved from https://jscholarship.library.jhu.edu/items/f749ee85-0cbf-4dd1-a613-f062155293c5

Tyler, B., Estrella, D., Britton, T., Nguyen, K., Iveland, A., Nilsen, K., Arnett, E., & Valcarcel, J. (2020). What education leaders can learn about NGSS implementation: Highlights from the Early Implementers Initiative. WestEd. Retrieved from https://www.wested.org/resource/ngss-early-implementers-initiative-final-evaluation/

Explorelearning®

Research Summary

EXPLORELEARNING GIZMOS:

THE RESEARCH BEHIND OUR PROGRAM

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1. Introduction

Gizmos online simulations and case studies bring the power of inquiry-based learning to teachers and students in grades 3–12. *Gizmos* help teachers take advantage of research-proven instructional strategies and enable students of all ability levels to develop conceptual understanding in math and science. With more than 500 academic learning standards-aligned *Gizmos* at their disposal, teachers can supplement and enhance students' blended learning experiences with interactive visualizations of math and scientific concepts that are tough to teach and tough to understand.

Gizmos present topics in ways that make the math and science concepts more approachable and understandable using scenarios and experiments that wouldn't typically be able to be taught in a classroom setting. Students graph, measure, and compare. They predict and prove. With *Gizmos* students don't just act like scientists and mathematicians, they are scientists and mathematicians. And *Gizmos* are seriously fun!

1.1 Virtual Instruction to Support Accessible and Equitable Remote Learning

Gizmos support the three dimensions of the National Research Council's (NRC) Framework for K–12 Science Education: disciplinary core ideas, crosscutting concepts, and science and engineering practices. With *Gizmos* inquiry-based simulations, students manipulate key variables, generate and test hypotheses, and engage in extensive "what-if" investigations. Students participate in interactive experiments as they explore the concepts behind the phenomena, ultimately coming to understand the deeper underlying concept of a topic and applying it to solving new scenarios and problems—so they are doing much more than filling in a formula or learning only definitions.

***GIZMOS* KEY FEATURES:**

- Hundreds of phenomenon-based science simulations
- Correlations to state math and science standards and more than 300 leading textbooks
- Self-directed, inquiry-based lessons for every Gizmo that are ready to use as-is or customizable
- Flexible for use in whole-group instruction, in small groups, individually, or at home
- Easy-to-use interface so that time is spent teaching and learning math or science, not the technology

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1.2 Instructional Materials

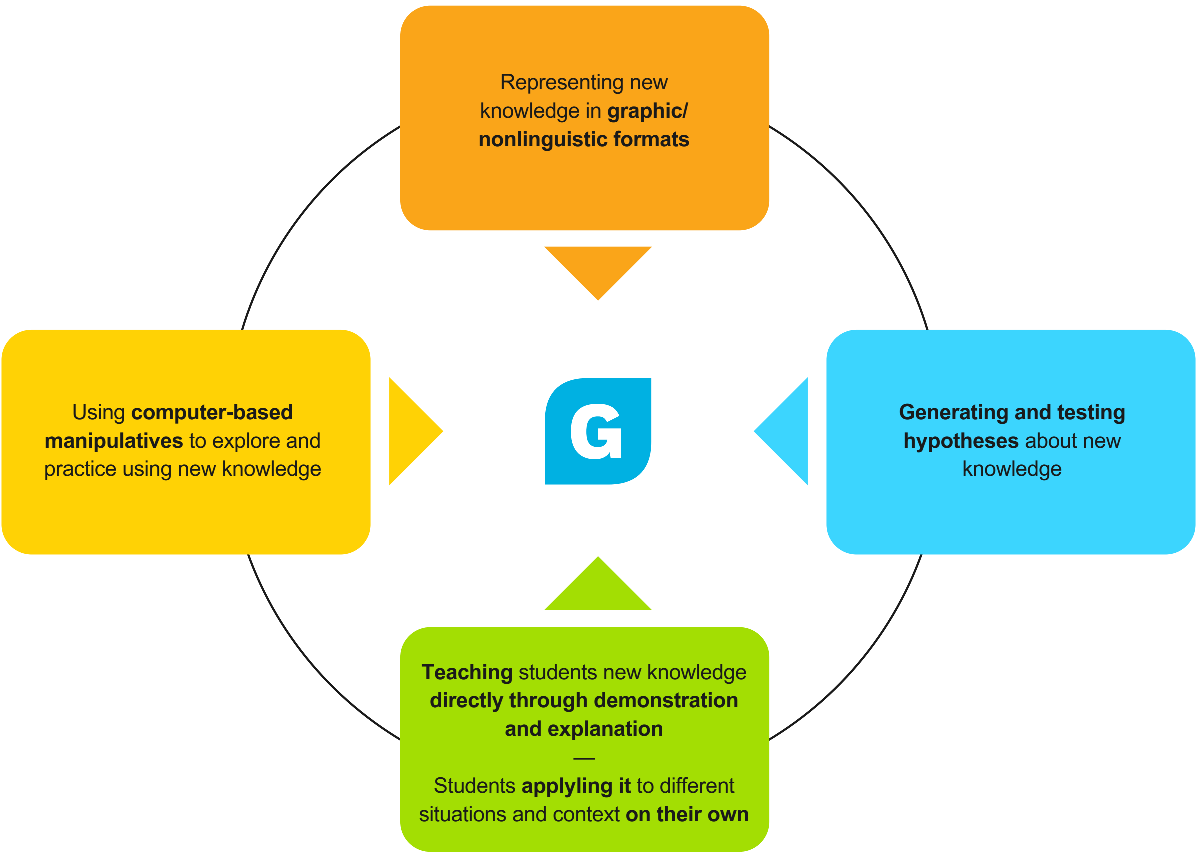
Every *Gizmo* offers a complete set of instructional materials to support the deep understanding of foundational and more complex concepts and principles. All materials can be used as-is or can be customized by teachers. All lesson materials can be viewed, printed, or downloaded (.doc or .pdf; student exploration sheets are now available as Google docs) from the program. Materials include:

- A teacher guide that provides an overview of the lesson, learning objectives, vocabulary, suggested lesson sequence, suggestions for pre- and post-*Gizmo* lessons, mathematical/scientific background, and selected web resources
- A student exploration sheet (and answer key) that guides students through multiple lessons designed to give structure to the lesson and ensure students grasp the main concepts without diminishing their ability to explore the simulation on their own
- A vocabulary sheet that presents the key language and concepts from the lesson
- Assessment questions that provide a check of understanding with built-in multiple-choice quizzes that offer immediate student feedback and teacher report assessment results.

Each *Gizmo* focuses on a related set of skills or concepts, with multiple lesson activities (typically three) at varied levels of complexity and depth of content to support scaffolding. The activities can be assigned one-by-one or together to cover the range of topics covered by the *Gizmo*. The ability to customize also allows teachers to modify lessons to meet student needs. Typical lessons start with students engaging in an activity that helps them understand the *Gizmo* concept and see the results of their exploration. Then, students are prompted to make predictions about new situations based on their prior experiments, after which they verify their answers using the *Gizmo*.

2. Our Research Base: Why *Gizmos* Work

Gizmos uses an approach to learning that has been validated by extensive research as a highly effective way to build conceptual understanding in math and science. In a meta-analysis of over 100 research studies involving 4,000+ experimental/control group comparisons (Marzano, 1998), the following *Gizmos* instructional techniques were all shown to have a large, *positive impact on student achievement*.



2.1 Representing new knowledge in graphic/nonlinguistic formats

Research in cognitive psychology indicates that our brains store knowledge using both words and images, and instruction that targets and engages both has been shown to significantly increase students' comprehension and retention.

Visual model of equivalent fractions

The *Gizmos* in the ExploreLearning library cover hundreds of topics in math and science with interactive visual models. For example, *Gizmos* help students visualize the flow of current in an electrical circuit they have designed themselves, study the process of triangulation in determining an earthquake's epicenter, and identify the role of the sun and moon in the fluctuation of ocean tides.

2.2 Using manipulatives to explore new knowledge and practice applying it

Manipulatives are concrete or symbolic artifacts that students interact with while learning new topics. They enable active exploration of abstract concepts. Research has shown that computer-based manipulatives are even more effective than ones involving physical objects, in part because they can dynamically link multiple representations together (Clements & McMillen, 1996). For example, students learning about systems of linear equations can use *Gizmos* to manipulate lines on a graph and instantly see the results of their actions as each of the multiple representations (algebraic, tabular, graphical) updates in real-time.

Computer manipulatives link the concrete and the symbolic by means of feedback.
For example, a major advantage of the computer is the ability to associate active experience with manipulatives to symbolic representations. The computer connects manipulatives that students make, move, and change with numbers and words. Many students fail to relate their actions on manipulatives with the notation system used to describe these actions. The computer links the two.

Computer manipulatives dynamically link multiple representations.
These can help students connect many types of representations, such as pictures, tables, graphs, and equations…[allowing] students to see immediately the changes in a graph as they change data in a table. These links can also be dynamic. Students might stretch a computer geoboard's rectangle and see the measures of the sides, perimeter, and area change with their actions.

Computers change the very nature of the manipulative.
Students can do things [using computer-based manipulatives] that they cannot do with physical manipulatives.

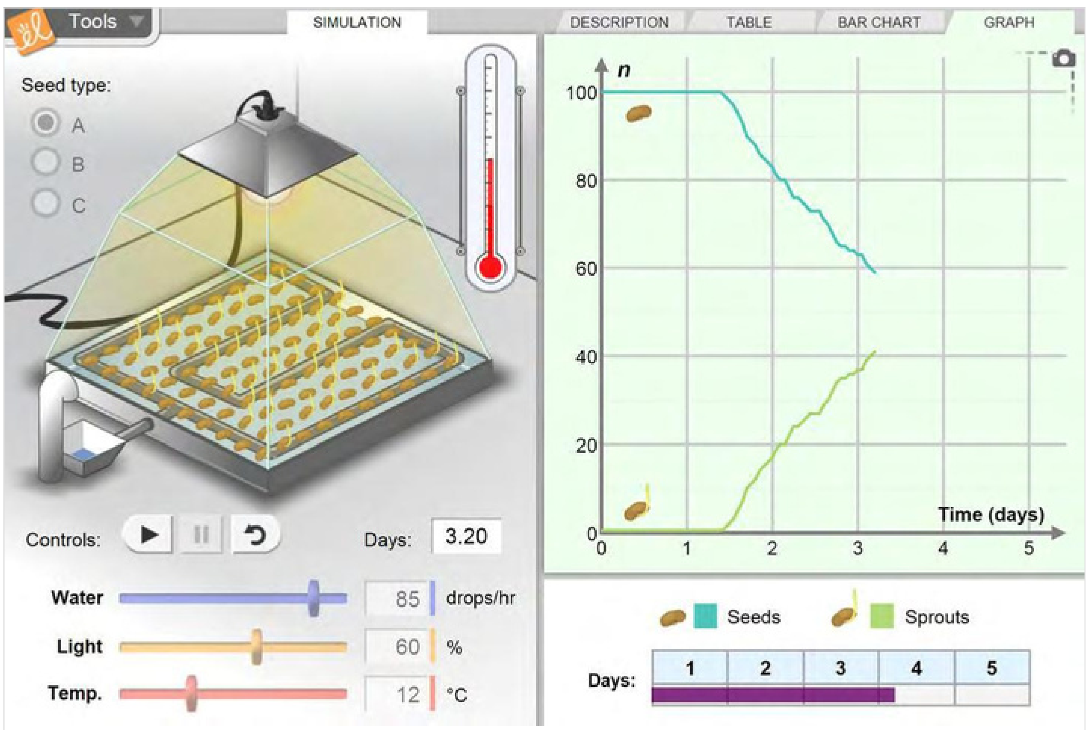
2.3 Supporting application of new knowledge

The Marzano meta-analysis notes that students learn effectively and efficiently when students are encouraged to apply conceptual categories, generalizations, and principles to new situations. Ideally, educational software should support teachers in presenting new knowledge to students as well as supporting students in applying and extending what they have learned.

2.4 Generating and testing hypotheses about new knowledge

Research has shown that students derive the greatest value from manipulatives when they are guided in their use. The full pedagogical power of the manipulative is only achieved when students mindfully reflect on the actions they perform and how the manipulative responds to them.

The guides that accompany every Gizmo are designed to support and stimulate this type of mindful interaction. A typical guide starts with students engaging in a set of exercises where they perform specific actions and record the results. Then, they are prompted to make predictions about new situations, after which they verify their answers using the Gizmo.



3. Independent Research Shows that *Gizmos* Work

A number of independent studies by university-affiliated researchers over the past 15 years have demonstrated the efficacy of *Gizmos*. These studies have found significant positive impacts from *Gizmos* use in the classroom on student achievement, classroom engagement, content knowledge, and knowledge application in both math and science. Here we briefly summarize a number of these articles. For more details, please see the references listed at the end of this report.

3.1 Higher state and standardized test scores

A group of 4th grade students at a small urban school in New York state were randomly assigned to receive either traditional classroom science lab activities (control group) or *Gizmos* activities once a week over the course of 8 weeks. Students who used *Gizmos* ***scored higher on the New York State Intermediate Level Science Assessment Test*** compared the control group. All students in the study were African American and eligible for Free or Reduced Price Lunch (Sudlow-Naggie, 2020).

RESEARCH ON GIZMOS HAS BEEN CONDUCTED BY RESEARCHERS FROM SEVERAL UNIVERSITIES, INCLUDING:

University of Virginia
University of Georgia
The Ohio State University
University of North Carolina
University of South Carolina
George Mason University
The State University of New York

8th grade students attending a Title I middle school in Florida who used *Gizmos* three times per month ***scored higher on the Florida Comprehensive Assessment Test (FCAT) Physical & Chemical science category*** compared to a control cohort who did not use *Gizmos* (Hall, 2014).

After 6 months of classroom *Gizmos* usage, 5th grade students at a Title I school in a large school district in Texas showed ***increases on the state science assessment (STAAR)***. The program was particularly beneficial for Hispanic, African American, and Economically Disadvantaged students (Smith, 2012).

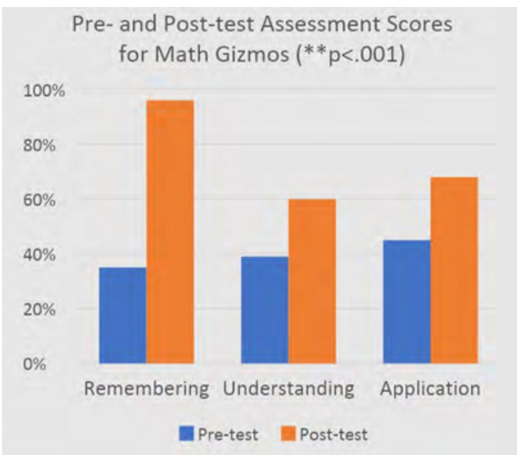
An RCT (randomized, controlled trial) by the Maine Department of Education evaluated the impact of a a technology-centered two-year professional development program, which involved incorporating *Gizmos* into mathematics instruction, across 56 rural middle schools. At post-test, ***their students significantly outperformed those in the control group on standardized mathematics tests*** (Silvernail, 2008).

A teacher training program which incorporated *Gizmos* was associated with increases in scores on the Texas Assessment of Knowledge and Skills (TAKS) for 8th Grade Science (Knezek et al., 2009).

3.2 *Gizmos* increase classroom engagement

A study of a 6th grade mathematics class found that students randomly assigned to a math *Gizmo* lesson showed ***higher levels of classroom engagement and excitement compared to a control group*** of students who used a non-virtual lesson. Additionally, the *Gizmos* using students were significantly ***more likely to endorse positive statements about the value of math in cognitive growth*** (Inman, 2018).

3.3 *Gizmos* support knowledge gains and application of knowledge to new problems



The chart reflects the percentage of correct answers before and after using a math Gizmo, as reported in Kay & Lauricella (2018).

127 4th – 6th grade students were given a math *Gizmo* lesson followed by teacher ratings of student knowledge and student perception surveys. ***Both measures indicated a significant increase in academic performance, including both content understanding and knowledge application*** (Kay & Lauricella, 2018)

A study of 6th grade students over a 4-week period found that engaging with the *Integer Addition and Subtraction* *Gizmo* led to significant gains from pre-to-post test measures of both addition and subtraction concepts. Additionally, in post-test interviews, students demonstrated an increased ability to make connections between verbal and pictorial representations of integer values (Bolyard & Moyer-Packenham, 2012).

Smetana & Bell (2014) explored the learning outcomes from the use of three different science *Gizmos* within a high school chemistry unit. Two classes were randomly assigned to use the *Gizmos* within either a whole-class or a small group instructional setting. Using pre- and post- assessments of conceptual understanding, the study found significant gains in knowledge for both instructional settings, supporting the efficacy of *Gizmos* in a variety of implementations. Highly collaborative talk was also observed in the whole class setting.

A recently published study (Haji Ismail et al., 2023) using a pre- and post-test methodology found that *Gizmos* significantly increased knowledge of addition and subtraction of integers. Additionally, interviews with a subsample of the students found that they felt confused and challenged by the pre-test, but found the post-test easy and reported having the knowledge and confidence to answer it. Below is an example of one child's interview answers:

I: I'm going to start with question. How did you find test before & after intervention?
D: Um ... before the intervention, it was very difficult to learn. It was very difficult to answer the questions.
I: Have you studied integers before?
D: Yes. But I still did not understand.
I: How do you feel after the intervention?
D: I was excited because I understood it. I was able to answer the questions easily.

A pre-post interview study by researchers at The Ohio State University found that exposure to a *Gizmos* math simulation led to ***increased understanding of a related math problem, including producing more accurate numerical solutions and using more advanced methods for problem solving*** (Manouchehri & Sanjari, 2019). For example, one student demonstrated significant difficulty accurately representing physical quantities mathematically (Figure 1). After experience with a related Gizmo, the student correctly represented locations on a line, distinguished the scaling of the problem, and accurately interpreted units of distance and time (Figure 2).

Figure 1: M’s incorrect representation at pre-test

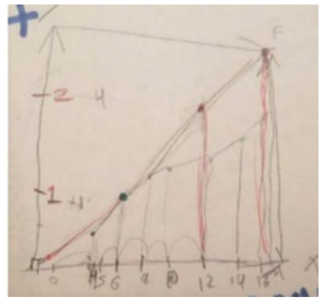


Figure 2:
M’s correct representation at post-test

4. Impact and Usage Research: Current and Future Plans

4.1 Meeting ESSA Standards for Evidence-Based Interventions

The Every Student Succeeds Act (ESSA), the 2015 national education law that replaced No Child Left Behind, is focused on state and district decision-making. The ESSA Tiers of Evidence provide districts and schools with a framework for determining which programs, practices, strategies, and interventions work in which contexts and for which students. The following section details research completed or currently underway to meet the four levels of evidence under ESSA.

Tier	Strength of Evidence	Type of Evidence
1	Strong	Supported by one or more well-designed and well-implemented **experimental studies**
2	Moderate	Supported by one or more well-designed and well-implemented **quasi-experimental studies**
3	Promising	Supported by one or more well-designed and well-implemented **correlational studies** (with statistical controls for selection bias)
4	Demonstrates a Rationale	Based on high-quality **research** findings or positive evaluation that the activity, strategy, or invention is likely to improve student outcomes or other relevant outcomes

ESSA Tier 4: Demonstrates a Rationale

Gizmos meets the ESSA evidence requirements for Level IV (Promising Evidence) by the following criteria:

- **Detailed *Gizmos* logic model**, informed by previous, high-quality research
- Planned and underway efforts to study the effects of using *Gizmos* (see below)

ESSA Tier 3: Promising Evidence

We are actively working with large and small school districts already using *Gizmos* to gather and analyze data from the 2022-2023 school year. We will analyze correlations between *Gizmos* usage, student engagement, and state-level science exams for middle and high school students. Preliminary results are expected by summer 2023.

ESSA Tier 2: Moderate Evidence

We are currently working with a large, urban district to collect and analyze quasi-experimental data on student usage of *Gizmos* and academic outcome measures (e.g., EOC grades, NWEA MAP Growth, statewide standardized tests) in a new district-wide roll out. Preliminary results are expected by summer 2024.

ESSA Tier 1: Strong Evidence

We are currently working to recruit a large district to participate in a randomized control efficacy study in the 2023-2024 school year. This impact study will provide the strongest evidence of the efficacy of *Gizmos* for increasing student engagement, motivation, and achievement in math and/or science. Preliminary results are expected by summer 2024.

4.2 *Collab Crew*: A New Initiative for Sustaining Research

ExploreLearning designs research-grounded products that are rooted in educational and learning sciences. To support this aim, ExploreLearning recently built out a user engagement group called the "*Collab Crew*" which invites math and science teachers, and administrators to work collaboratively with the Product and Research Teams. Members are invited to contribute to product reviews, surveys, data sharing, co-testing, and other opportunities which provide valuable data and feedback to support product design and improvement and ultimately ensure success in the classroom. The Collab Crew is currently comprised of almost 500 members, including over 350 teachers representing all grades from K-12.

4.3 Recent Insights into Product Usage and Efficacy

The recent hire of a Senior Researcher has increased the capacity for internal research on product usage and efficacy. In the 2022-23 school year, Collab Crew members have participated in surveys of product usage, student achievement, and product feedback; focus groups on new product features and implementation strategies; and 1:1 interviews for product ideation, proposal reviews, and product efficacy.

Here we highlight some of the key outcomes of our most recent research efforts:

- By analyzing user login data, survey results, and user interviews, we have learned more about implementation strategies in the classroom, including usage patterns, as well as areas for improvement that are being factored into the design of new *Gizmos*
- Surveys were designed to be launched at regular interviews throughout the school year to provide more timely and ongoing feedback to product developers to incorporate into the design of new *Gizmos*.
- Efforts are being made to identify specific teacher needs in supporting student learning through surveys and interviews.
- Increased capacity for Beta testing new features and *Gizmos* to ensure applicability to a wide range of students and teacher use cases.

About ExploreLearning

ExploreLearning LLC, based in Charlottesville, VA, was founded in 1999 by educators looking for new ways to inspire students across grades K–12 and help them succeed in math and science. With a philosophy of life-long learning driving our thought leadership, a careful attention to the current needs of educators in today's rapidly-shifting educational culture, and a legacy of proven results, ExploreLearning is the best combination of proven expertise and innovative solutions over time to meet today's and tomorrow's educational challenges.

Our four digital programs (*Reflex*®, *Frax*®, *Science4Us*®, and *Gizmos*®) are currently used in classrooms in every state in the U.S. and more than 80 countries worldwide. Our programs are state- and national-standards aligned, including Next Generation Science Standards (NGSS) and the Standards for Mathematical Practice (SMP). ExploreLearning is a recognized leader in the educational software market, earning many major EdTech awards.

We aim to foster student success through the use of galvanizing, age-appropriate multimedia, including interactive simulations, STEM case studies, adaptive games, instructional videos, and much more. Our development team of engineers, researchers, and instructional-design experts, most of whom are former educators, are continually innovating beyond the latest advancements in instructional pedagogy and edtech. Our programs support students in developing mastery of fundamental skills and deep conceptual understanding in math and science, while also fully engaging them in the process of internalized learning, promoting growth mindset, resiliency, productive struggle, and perseverance.

Our goal is to provide educators with captivating, best-in-class digital learning in math and science that helps students reach their full potential. We firmly believe that teachers are mission-critical, i.e., the greatest influence on student success. We also believe that data, instruction, and practice, when operating in tandem, are paramount to improving student learning and academic achievement. In support of these foundational beliefs, we deliver curricula, professional learning, and implementation and technical support services that:

- Combine research-proven instructional methods and innovative technology
- Enable equitable access to math and science learning for all students
- Build strong, lasting foundations for student success by developing procedural and conceptual understanding
- Supplement core curricula with flexible digital and blended implementation
- Create positive outcomes and results for both students and teachers

References

Bolyard, J., & Moyer-Packenham, P. (2012). Making sense of integer arithmetic: The effect of using virtual manipulatives on students' representational fluency. *Journal of Computers in Mathematics and Science Teaching, 31*(2), 93-113.

Clements, D. H., & McMillen, S. (1996). Rethinking "concrete" manipulatives. *Teaching children mathematics*, 2(5), 270-279.

Haji Ismail, N. F., Shahrill, M., & Asamoah, D. (2023). Learning through virtual manipulatives: Investigating the impact of Gizmos-based lessons on students' performance in integers. *Contemporary Mathematics and Science Education, 4*(1), ep23009.

Hall, T. E. (2014). Simulations in Inquiry-Based Learning [Doctoral dissertation, Lynn University]. ***https://spiral.lynn.edu/etds/310***

Inman, B. L. (2018). *Gizmos Computer Simulations in the Mathematics Classroom.* (Publication No. 13426018) [Doctoral dissertation, Morehead State University]. ProQuest Dissertations Publishing.

Kay, R., & Lauricella, S. (2018, June). *Exploring the use of mathematics apps for elementary school students*. In EdMedia+ Innovate Learning (pp. 206-211). Association for the Advancement of Computing in Education (AACE)

Knezek, G., Christensen, R., Owen, A., Farsaii, S., McPherson, R., Brogdon, S. & Jung, J. (2009). *Relationship of Educator Professional Development for Interactive Online Simulations to Eighth Grade Student Achievement in Math and Science.* In G. Siemens & C. Fulford (Eds.), Proceedings of ED-MEDIA 2009--World Conference on Educational Multimedia, Hypermedia & Telecommunications (pp. 3276-3281). Honolulu, HI, USA: Association for the Advancement of Computing in Education (AACE).

Manouchehri, A., & Sanjari, A. (2019). *Examining Mathematical Modeling of Fifth Graders: Use of Interactive Computer Simulations.* Paper presented at the Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education (41st, St. Louis, MO, Nov 14-17, 2019)

Marzano, R. J. (1998) *A Theory-Based Meta-Analysis of Research on Instruction.* Aurora, Colorado, Mid-continent Regional Educational Laboratory. Available from: **http://www.peecworks.org/PEEC/PEEC_Research/I01795EFA.2/Marzano%20Instruction%20Meta_An.pdf**

Silvernail, D. (2008). *Maine's impact study of technology in mathematics* (MISTM). In Annual Meeting of the American Educational Research Association, New York, NY (pp. 1-21).

Smetana, L. K., & Bell, R. L. (2014). Which setting to choose: Comparison of whole-class vs. small-group computer simulation use. *Journal of Science Education and Technology, 23*, 481-495.

Smith, S.N. (2012). *Using ExploreLearning's Science Simulations to Improve Student Achievement.* [Master's Dissertation, University of Texas Arlington]

Sudlow-Naggie, N. (2020). *The Effects of Virtual Laboratory Activities on Science Learning.* [Doctoral dissertation, St. John's University]. **http://orcid.org/0000-0002-4753-5569**

ExploreLearning®

WHY GIZMOS WORK

Empirical Evidence for the Instructional Effectiveness Of ExploreLearning Interactive Content

Paul Cholmsky
Director of Research & Design
ExploreLearning

Winter 2003 (Updated Fall 2022)

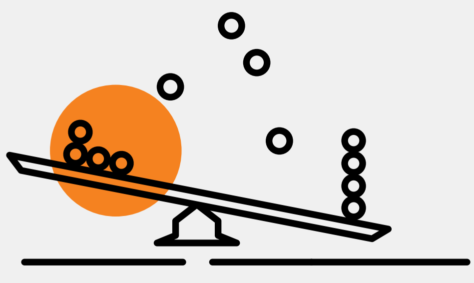


Table of Contents

1. Introduction

Meta-analysis of **educational research** provides **empirical evidence** for the **instructional effectiveness** of ExploreLearning **Gizmos**.

1.1 What is 'empirical evidence of instructional effectiveness'?

Empirical evidence of instructional effectiveness means that claims about the effectiveness of a given instructional method or product are substantiated by scientific research. This research should be based on experimental studies where the effects of specific variables on student performance are isolated and measured. Ideally, these studies are conducted in actual classrooms across several different school settings to verify that the instructional method or product will be effective for a wide range of students.

1.2 Why is empirical evidence of instructional effectiveness important?

Grounding instructional decisions in scientific research reduces the influence of pedagogical fads and gurus. Rather than struggling to constantly change and adapt to 'the latest thing,' teachers can base their teaching methods on specific pedagogical principles that have been demonstrated to be successful. These research-validated methods provide a solid foundation upon which teachers can build and adapt their own teaching styles to best respond to the diverse needs of their students.

The importance of using scientific research to drive educational decision-making has recently been ratified into law. The *No Child Left Behind Act of 2001* (NCLB), which reauthorized the Elementary and Secondary Education Act, requires that "scientifically based research" be used as the basis for decisions about instructional methods and about federally-funded education programs in general. The strong emphasis placed on scientifically based research is evident from the fact that the phrase appears more than 100 times in the NCLB legislation (Neuman, 2002).

The NCLB legislation also mandates that scientific research be factored into decisions regarding which educational products and technologies get adopted and used in K-12 classrooms. Educational technology can play an important role in disseminating best practices, because it can make research-validated instructional methods more practical to implement in the classroom on a regular basis. For example, teachers often struggle to incorporate opportunities for hands-on exploration of math and science concepts in their lesson plans due to time constraints. Well-designed computer simulations can make the incorporation of manipulatives in lesson plans much easier and enable students to develop a richer and deeper conceptual understanding in a shorter period of time.

1.3 What kinds of empirical evidence are acceptable?

According to the federally-funded paper, *Using Research and Reason in Education: How Teachers Can Use Scientifically Based Research to Make Curricular & Instructional Decisions* (Stanovich & Stanovich, 2003), empirical evidence of instructional effectiveness can come from any of the following sources:

- Demonstrated student achievement in formal testing situations implemented by the teacher, school district, or state;
- Published findings of research-based evidence that the instructional methods being used by teachers lead to student achievement; or
- Proof of reason-based practice that converges with a **research-based consensus in the scientific literature**.

1.4 How can a research-based consensus in the scientific literature be identified?

Scientific research is not infallible. There is always the possibility that individual studies may arrive at erroneous findings by chance or through experimenter error. Basing instructional practice on the results of a single study is therefore not advisable. However, asking educators to familiarize themselves with the literally thousands of research studies available on instructional methods is obviously not a feasible approach either.

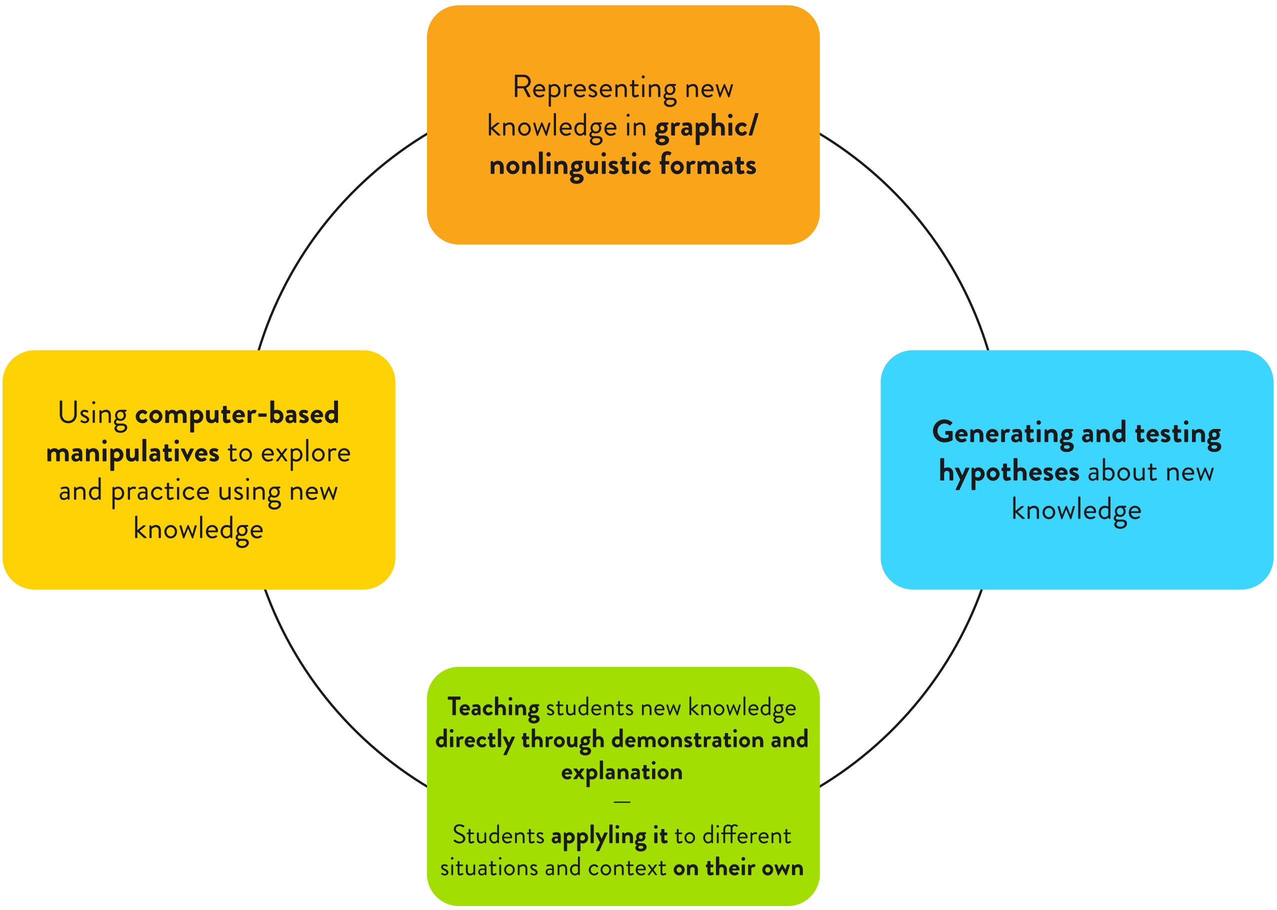
This challenge is not limited to educational research – the need to identify a research consensus from a large number of studies is common to most areas of scientific inquiry. To meet this need, a formal statistical method called *meta-analysis* has been developed for systematically comparing results across disparate studies. This method has been found to be very successful in medical research, and there is an increasing drive to make it the vehicle by which educational research is distilled for application in the nation's classrooms.

> More and more commentators on the educational research literature are calling for a greater emphasis on meta-analysis as a way of dampening the contentious disputes about conflicting studies that plague education and other behavioral sciences (Kavale & Forness, 1995; Rosnow & Rosenthal, 1989; Schmidt, 1996; Stanovich, 2001; Swanson, 1999). The method is useful for ending disputes that seem to be nothing more than a "he-said, she-said" debate. An emphasis on meta-analysis has often revealed that we actually have more stable and useful findings than is apparent from a perusal of the conflicts in our journals.
>
> (Stanovich & Stanovich , 2003, p.16-18)

This white paper is based on the findings reported in *A Theory-Based Meta-Analysis of Research on Instruction* (Marzano, 1998).

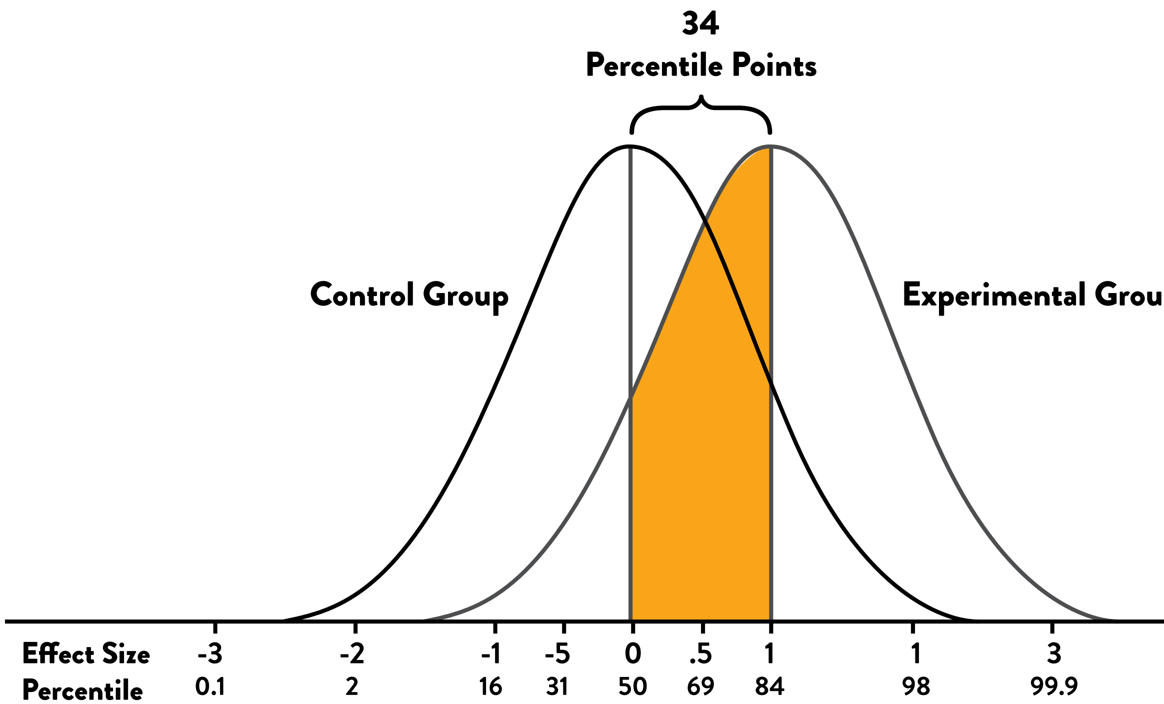
2. Research-validated instructional techniques

Using the summarized findings of over 100 research studies involving 4,000+ experimental/control group comparisons, the Marzano (1998) meta-analysis identified instructional techniques that had a positive impact on student achievement. This was done by calculating an *effect size* for each technique. Effect sizes are used in meta-analyses in order to synthesize results across numerous studies and arrive at an estimate of the typical effectiveness of a given technique. Effect sizes also enable researchers to compare the relative effectiveness of different techniques against each other.



Instructional techniques that have been proven effective through meta-analysis

The four instructional techniques in the graphic above were all shown to have an effect size greater than 1. An effect size that exceeds 1 means that the average student who benefited from a given instructional technique **outscored more than 84%** of students in control groups. Therefore, an average increase in student achievement of **more than 34 percentile points** is attributable to each of these four techniques.



Effect Size of **1** ➡ Average Percentile Point Gain of **34**

The effectiveness of these techniques likely comes as no surprise to experienced educators. For them, the results of the Marzano meta-analysis may only serve to confirm and validate what they have informally observed to be effective in their own classrooms over the years. However, a pragmatic gap often exists between what a teacher knows to be effective and what is possible for her to realistically implement in the classroom on a consistent basis. A common barrier inhibiting teachers from regularly and effectively deploying these research-validated techniques are the teaching tools at their disposal. Textbooks, whiteboards, video/film and overhead projectors support relatively passive student learners much more easily than they do active learning involving manipulatives, student-generated hypotheses, and so forth. As a result, even though teachers may have always suspected or known that these techniques were instructionally effective, the ever-present time crunch in the classroom may have precluded extensive use of them.

The next section of this white paper shows how ExploreLearning's computer-based interactive simulations (Gizmos®) are specifically designed to implement these research-validated instructional techniques in an effective and efficient manner.

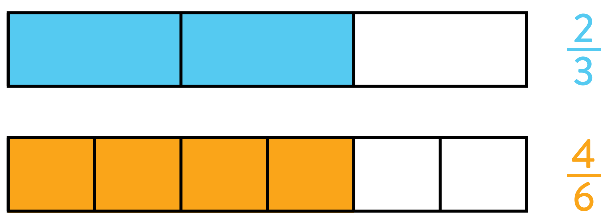
2.1 Representing new knowledge in graphic/nonlinguistic formats

META-ANALYSIS RESEARCH SUMMARY: IMAGE-BASED REPRESENTATIONS

Having students represent new knowledge in graphic/nonlinguistic formats results in an average percentile point gain of 39 (ES = 1.24).

SOURCE: Marzano (1998), p.106

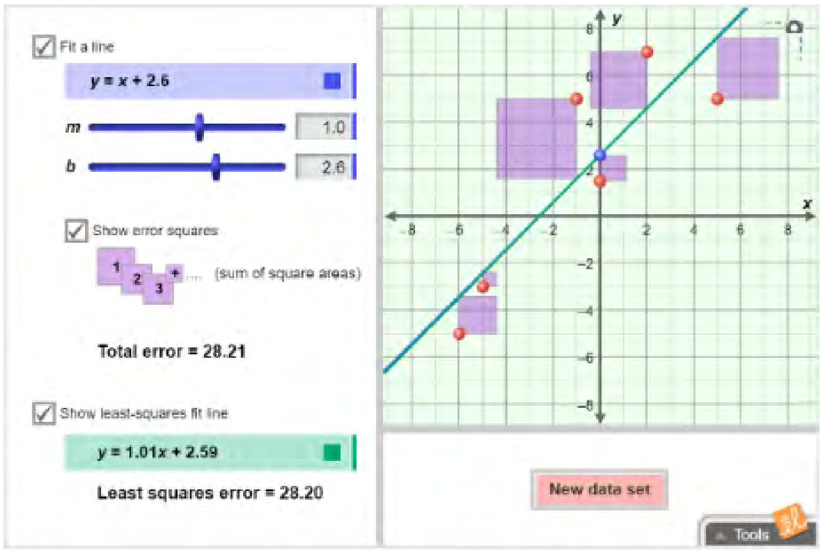
Research in cognitive psychology indicates that our brains store knowledge using both words *and* images. Instruction that targets and engages both of these systems of representation has been shown to significantly increase students' comprehension and retention. In mathematics, for example, constructing basic fraction models helps middle school students quickly see why the fractions $\frac{2}{3}$ and $\frac{4}{6}$ are equivalent:



Visual model of equivalent fractions

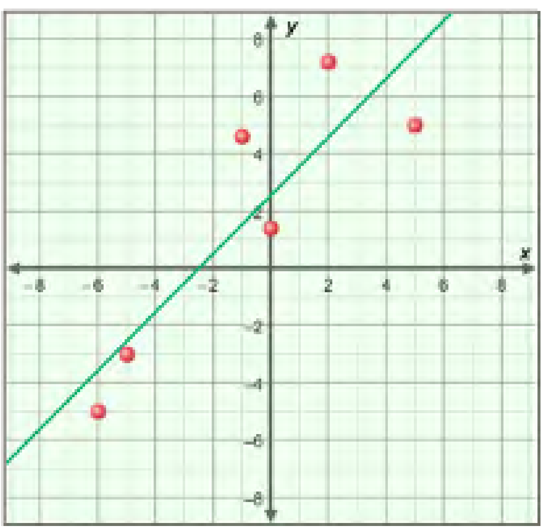
Nonlinguistic representations also provide strong support for more advanced mathematical concepts in algebra, geometry, statistics, and calculus. When learning how to find a line of best fit for a data set, for example, students need to understand that the least squares method calculates the total error for a given line using the sum of the squared deviations between that line and each value in the data set. The *Least-Squares Best Fit Lines Gizmo* has been designed to help students visualize this concept. In this Gizmo, squares are connected between each of the data points on the graph and the line being fitted to them. A given square's area therefore represents the squared vertical distance (i.e., the squared deviation) between the associated data value and the current line. [See screenshot on following page.]

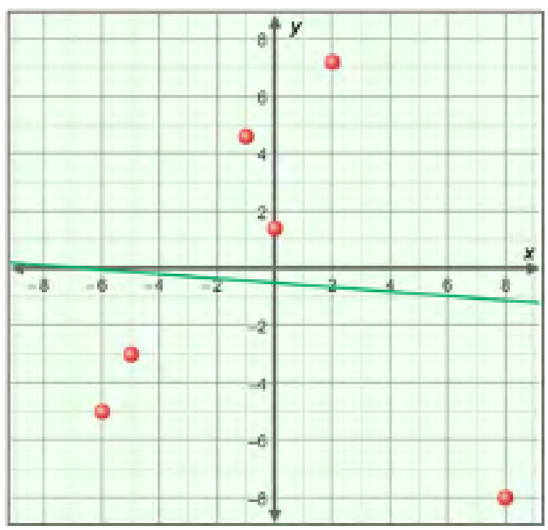
As students adjust the line's slope and y-intercept, the error squares' areas are immediately and continuously updated, as is a numerical display of the total error (i.e., the combined area of the error squares). This real-time updating allows students to manually fit a line by incrementally adjusting the slope and y-intercept of the line until the total error is minimized. [The slope and intercept can be varied by typing in new values, by adjusting sliders, or by dragging the line on the graph.] By trying to fit lines to data sets that have no linear relationship as well those that have strong linear relationships, students observe that regression lines are only reliable predictors of values in data sets that exhibit linear relationships. The Gizmo's interactive display thereby provides students with a nonlinguistic representation of both the least squares method and the degree of linear association between two variables.



[**Gizmo: Least-Squares Best Fit Lines**]

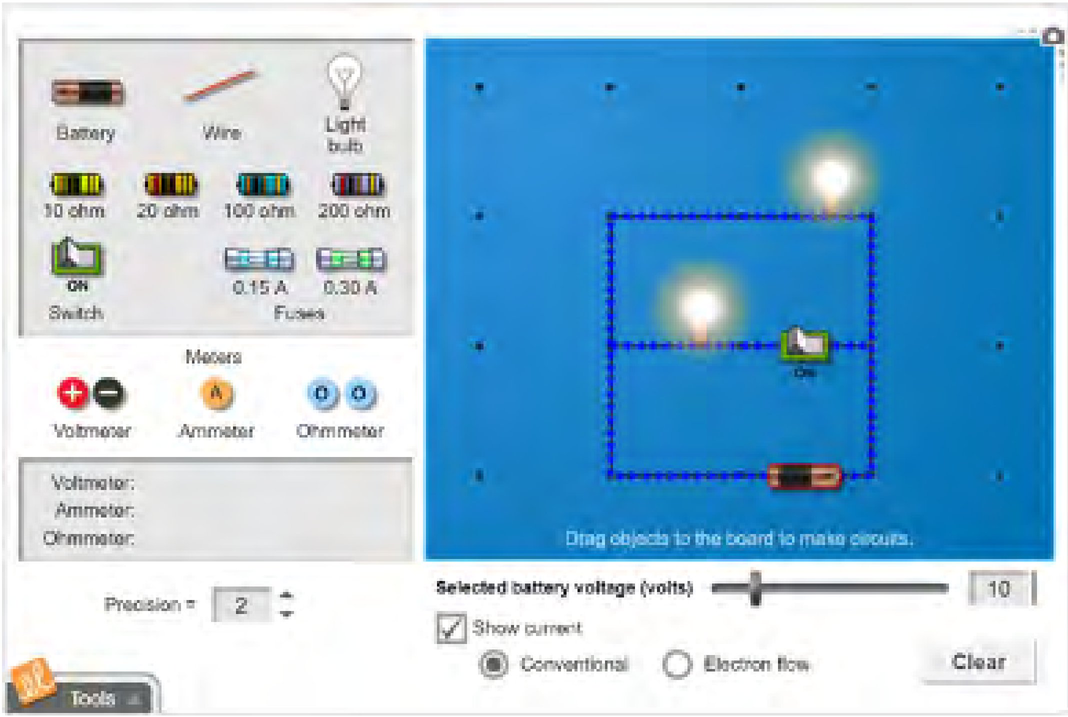
An added advantage of the visualization in this Gizmo is that students can directly manipulate individual data points by dragging them on the graph. This allows them to witness the effect an outlier in a small data set can have on a line of best fit calculated using the least squares method.



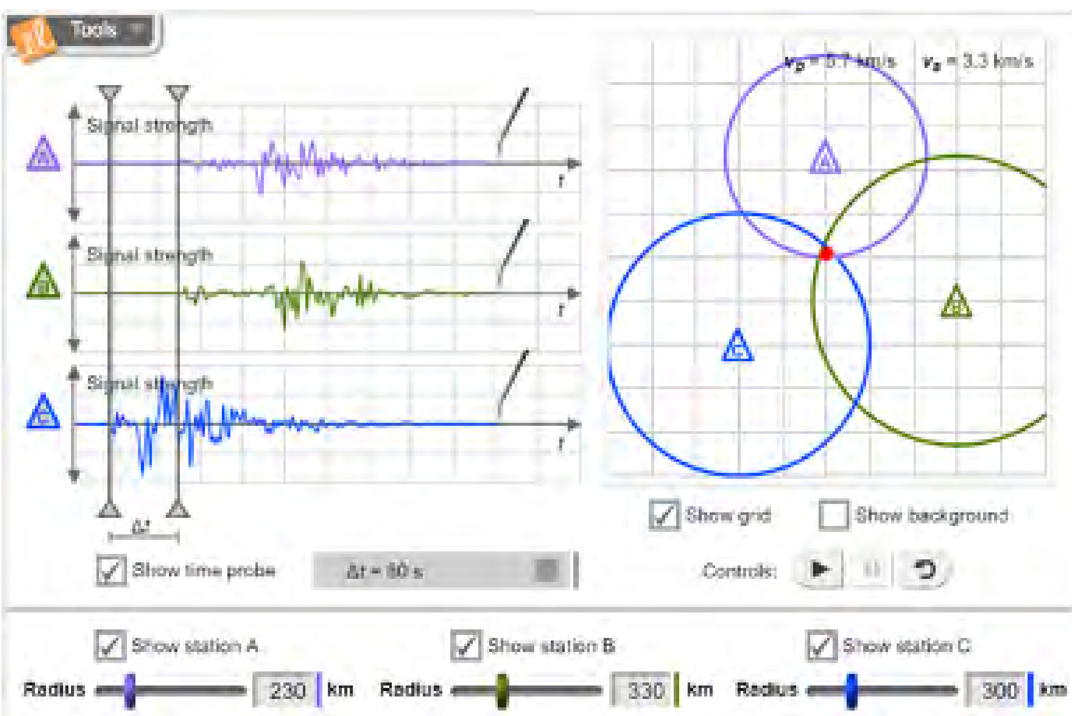


The power of these types of interactive animations is not limited to mathematics. There are numerous topics within the sciences that can be more effectively taught when they are supported by computer-based visual models. For example, interactive animations can help students to:

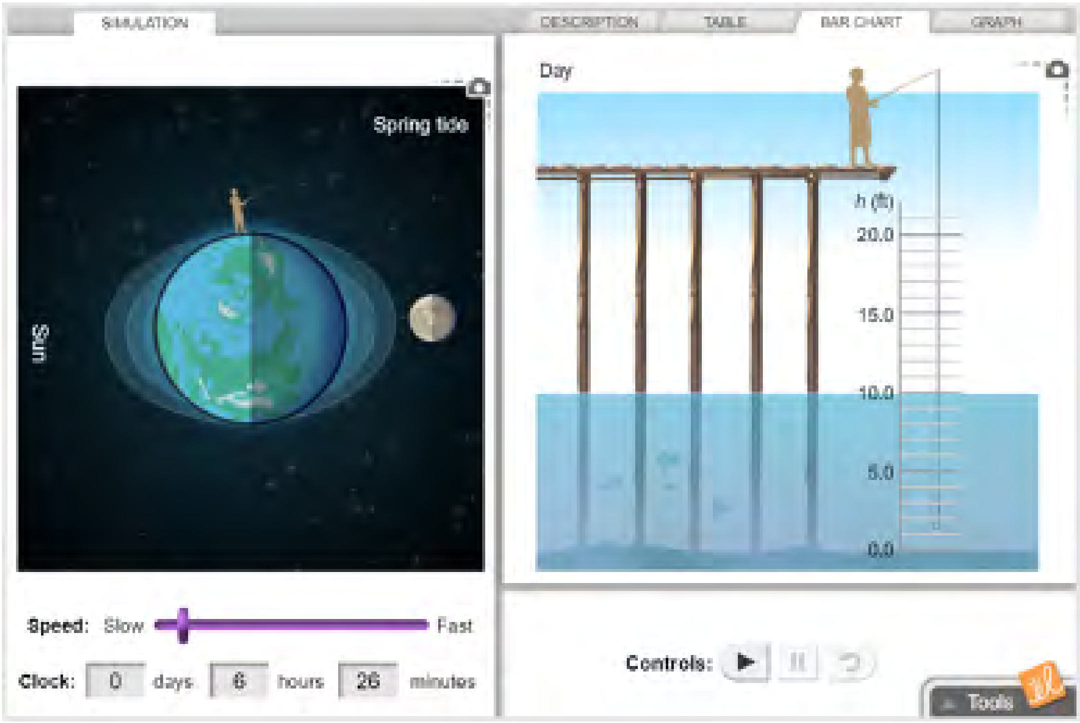
- Visualize the flow of current in an electrical circuit they have designed themselves;
- Study the process of triangulation in determining an earthquake's epicenter;
- Identify the role of the Sun and Moon in the fluctuation of ocean tides.



[Gizmo: Circuits](https://www.explorelearning.com)



Gizmo: Earthquakes 2 - Determination of Epicenter



Gizmo: Tides

When students are guided in generating and exploring nonlinguistic representations, the research shows that the effects on achievement are dramatic. As noted by Marzano in his meta-analysis, explicitly engaging students in the creation and usage of nonlinguistic representation has even been shown to stimulate and increase activity in the brain (Gerlic & Jausovec, 1999).

Unfortunately, research on actual classroom practice has also consistently shown a predominant emphasis on linguistic presentations of new knowledge to students (Marzano, Gaddy & Dean, 2000). Although many math and science textbooks have increased the number of images, diagrams, and other graphics on their pages in recent years, the fact that these visual representations cannot incorporate motion or be interactive constrains their instructional power. The pressure on educational publishers to keep page counts down in order to control costs also places a limit on the number of visuals that can be feasibly included in print-based materials. Although most teachers incorporate a certain number of visual representations into their teaching using whiteboards or overheads, it is often cumbersome and time-consuming to use these tools to enrich instruction with visuals in a comprehensive manner. From a practical standpoint, computer-based simulations are the ideal medium for visualizations of mathematical and scientific concepts.

An additional benefit of ExploreLearning's visual models is that they are user-manipulable, unlike video or film. Gizmos enable teachers and students to quickly progress through many different concepts or scenarios in a single session, dramatically expanding the range of what can be shown, explained, and explored in the classroom. Classroom discussions become more interactive and responsive to students' specific interests and difficulties, since their questions can be immediately examined and answered using manipulable visual models. Then, when students are studying on their own, Gizmos let them become active and engaged learners rather than passive observers of sequences of images in a textbook.

Research also shows how teachers can help students take full advantage of nonlinguistic representations by guiding them to incorporate visual models, diagrams and images into their study habits. The *What Works in Classroom Instruction* report (Marzano, Gaddy & Dean, 2000, p.40-47) stresses the importance of including diagrams and other images in note-taking:

> A very flexible note-taking strategy…is referred to as a *combination technique*….To use this note-taking strategy, students must stop periodically and make a graphic representation of their notes or portray the information in some visual way. At the end of their note-taking, or periodically throughout the process, students record summary statements of what they have learned….This note-taking method takes extra time, but is very useful because students review the information a number of times — first, as they record their notes; second, as they create drawings or other graphics for their notes; and third, as they record summary statements of what they have learned.
>
> …one of the common misconceptions about note-taking is that "less is more."…Researchers Nye, Crooks, Powlie, and Tripp (1984) explain that their examination of guides prepared by universities to teach students how to take notes found that "five out of ten guides examined emphasized the importance of keeping notes 'brief' and not putting too much material in notes" (p. 95). Yet, in their study of the effects of note-taking, Nye et al. found a *very strong relationship between the amount of information taken in notes and students' achievement on examinations*. (Emphasis ours.)

Note-taking strategies such as the combination technique are supported by the 'Copy Screen' button that is included in every ExploreLearning Gizmo. This button places a screenshot of the Gizmo into the computer's clipboard. [Many Gizmos also include 'camera' buttons that allow individual graphs or diagrams to be copied as well.] This enables students to quickly and easily paste images they generate using Gizmos into their notes or assignments. Teachers can also use this feature to add customized images to their own course materials or tests.

In summary, ExploreLearning Gizmos allow teachers to richly infuse their mathematics and science courses with high-quality, easy-to-use visual models.

2.2 Using manipulatives to explore new knowledge and practice applying it

META-ANALYSIS RESEARCH SUMMARY: COMPUTER-BASED MANIPULATIVES

Overall, the use of manipulatives is associated with an average percentile point gain of 31 (ES = .89). The specific use of computer simulations as manipulatives, however, produced the highest effect size (ES = 1.45), corresponding to an average percentile point gain of 43.

SOURCE: Marzano (1998), p.91

Manipulatives are concrete or symbolic artifacts that students interact with while learning new topics. They are powerful instructional aids because they enable active, hands-on exploration of abstract concepts. New mathematics and science (as well as ELA/literacy) standards and practices recognize the value of using models and simulations to build knowledge and skills.

Selected New Standards Related to Simulations

Mathematical Practices
(5) Use appropriate tools strategically. When making mathematical models, [students] know that technology can enable them to visualize the results of varying assumptions, explore consequences, and compare predictions with data.

Mathematics, Grade 3
3.NF.3.b Recognize and generate simple equivalent fractions, e.g., 1/2 = 2/4, 4/6 = 2/3). Explain why the fractions are equivalent, e.g., by using a visual fraction model.

Mathematics, Grades 9-12
F-IF.7 Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases.

Science and Engineering Practices
(1) Asking questions and defining problems. Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.

Physical Science, Grades 6-8
MS-PS4-2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. [Clarification Statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions.]

Life Sciences, Grades 9-12
HS-LS2-5. Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere. [Clarification Statement: Examples of models could include simulations and mathematical models.]

ELA/Literacy
RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

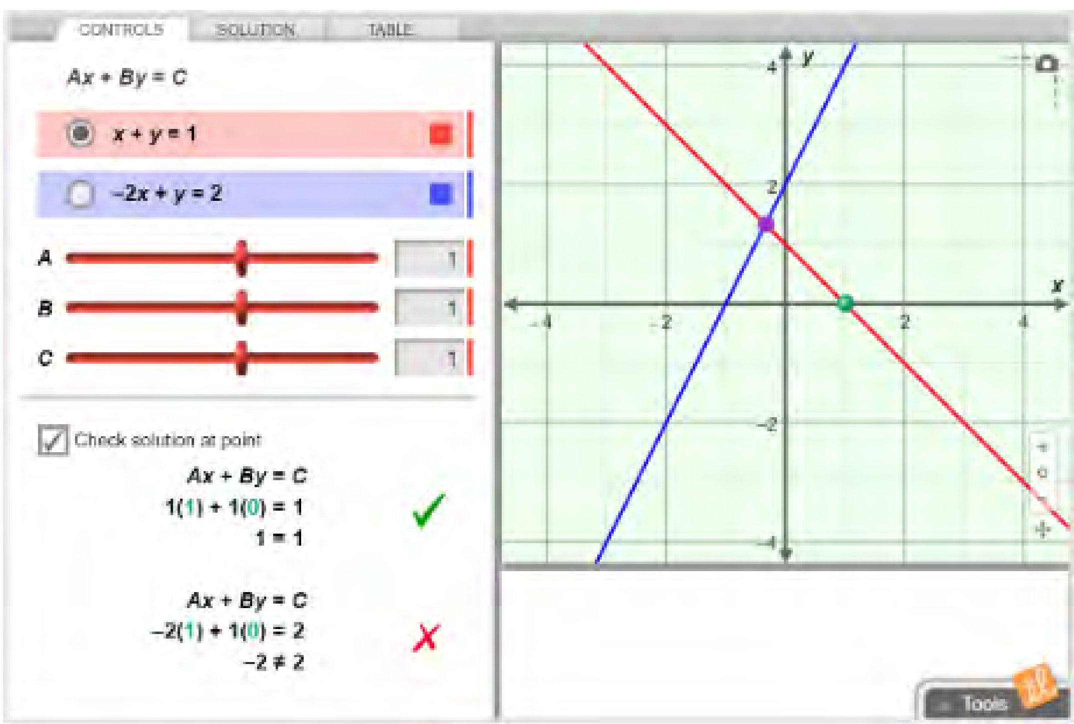
Research has shown that computer-based manipulatives are even more effective than ones involving physical objects. Some of the reasons for this increased effectiveness are outlined by Clements & McMillen (1996):

Computer manipulatives link the concrete and the symbolic by means of feedback.
For example, a major advantage of the computer is the ability to associate active experience with manipulatives to symbolic representations. The computer connects manipulatives that students make, move, and change with numbers and words. Many students fail to relate their actions on manipulatives with the notation system used to describe these actions. The computer links the two.

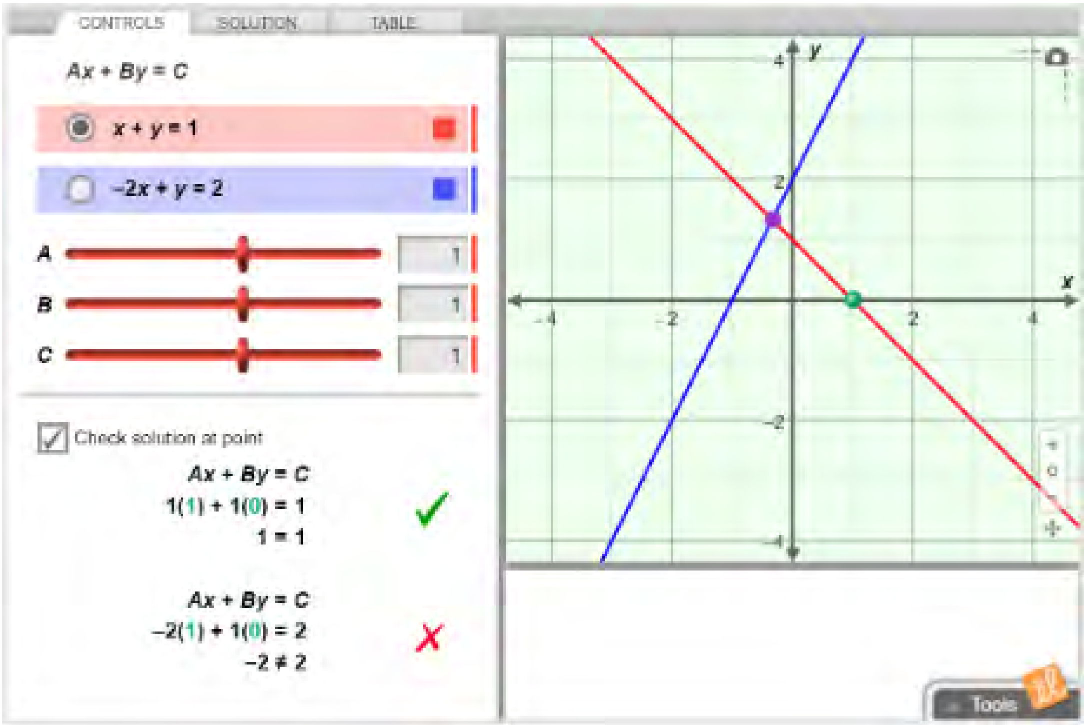
Computer manipulatives dynamically link multiple representations.
Such computer links can help students connect many types of representations, such as pictures, tables, graphs, and equations...[allowing] students to see immediately the changes in a graph as they change data in a table. These links can also be dynamic. Students might stretch a computer geoboard's rectangle and see the measures of the sides, perimeter, and area change with their actions.

Computers change the very nature of the manipulative.
Students can do things [using computer-based manipulatives] that they cannot do with physical manipulatives.

The ExploreLearning library contains many examples of the optimal computer manipulative described by Clements and McMillen. For example, students learning about systems of linear equations can access several Gizmos that focus on this topic, such as *Solving Linear Systems (Standard Form)*. Using these Gizmos, they can manipulate lines in their algebraic form or by dragging them directly on a graph, and instantly see the results of their actions as each of the multiple representations updates in real-time.



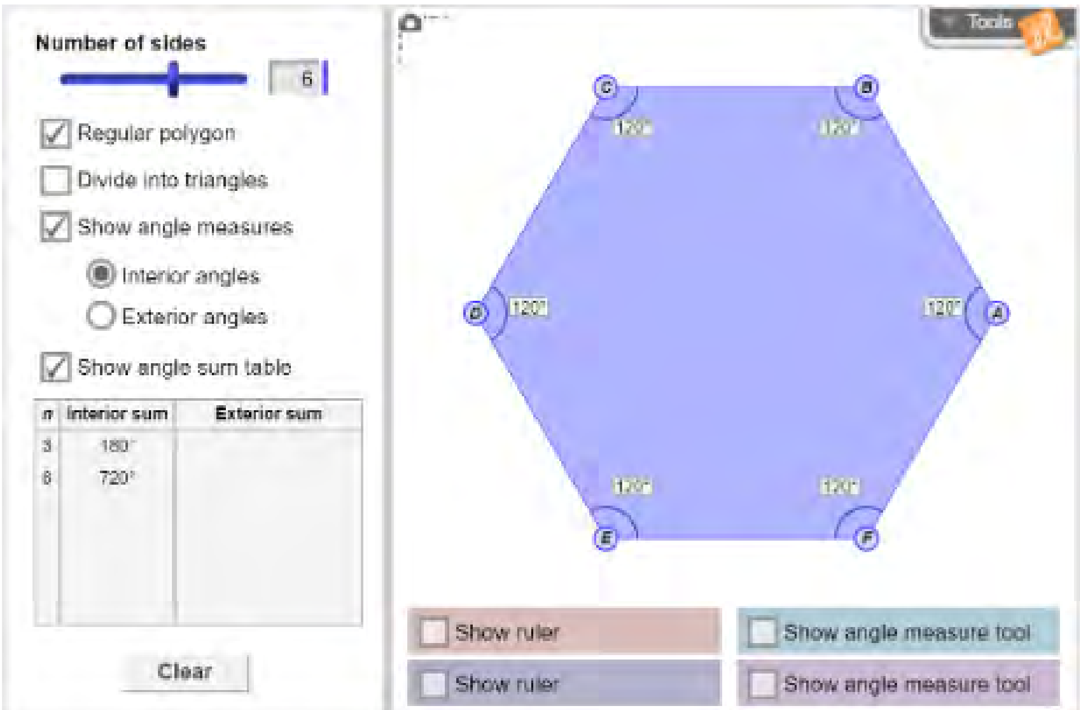
Gizmo: Solving Linear Systems (Standard Form)



[Gizmo: Solving Linear Systems (Standard Form)]

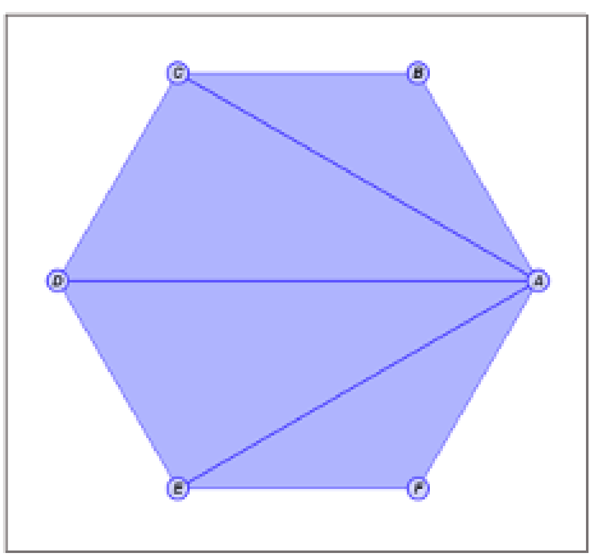
This is one of the many benefits that interactive manipulatives such as Gizmos provide over graphing calculators. Since graphing calculators cannot dynamically update a graph or show more than one graph at a time, comparing and contrasting characteristics between graphs is much more difficult for the student. Accurate comparisons are dependent on the student's ability to remember the salient features of graphs that were previously seen. This problem is eliminated with Gizmos, where dynamic displays enable the student to see the results of their changes as they perform them. The ability to see more than one representation (algebraic, tabular, graphical) at the same time also facilitates comparisons between these representations.

Geometry is another area where the benefits of computer-based manipulatives are easily seen. The ExploreLearning library contains a broad selection of Gizmos that allow real-time manipulation of geometric shapes by students in the manner prescribed by the research literature. In the *Polygon Angle Sum Gizmo*, for example, students specify the number of sides of an onscreen polygon, vary its shape by dragging its vertices, and then explore the sum of its interior and exterior angles:

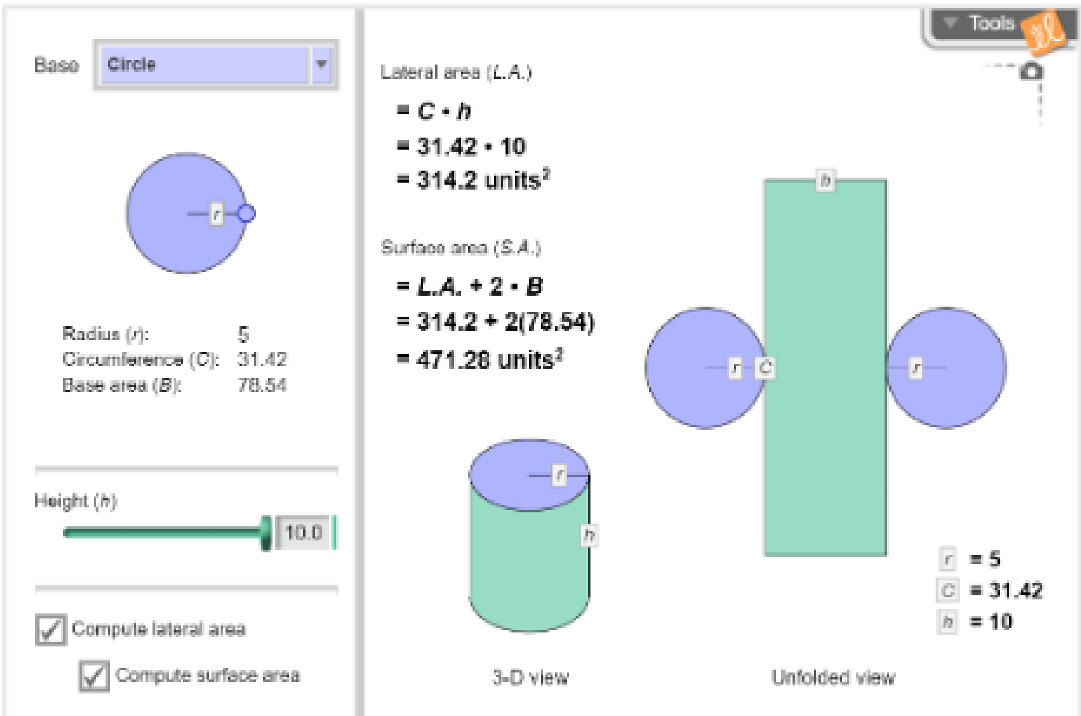


Gizmo: Polygon Angle Sum

The Gizmo also demonstrates how to divide student-generated polygons into triangles, enabling students to more easily see the relationship between the sum of the interior angles in the polygon and the number of sides it has:



Dynamic, manipulable models of cylinders, pyramids, cones, and prisms are provided in the ExploreLearning library to support students in understanding the logic underlying formulas for calculating areas and volumes of three-dimensional objects:



[Gizmo: Surface and Lateral Area of Prisms and Cylinders]

In summary, ExploreLearning Gizmos are flexible computer-based manipulatives that serve as critical bridges between concrete and abstract thinking. They provide a high degree of interactivity, enabling students to immediately observe the results of their experimentation and be able to relate concepts across multiple representations.

2.3 Generating and testing hypotheses about new knowledge

META-ANALYSIS RESEARCH SUMMARY: HYPOTHESIS GENERATION & TESTING

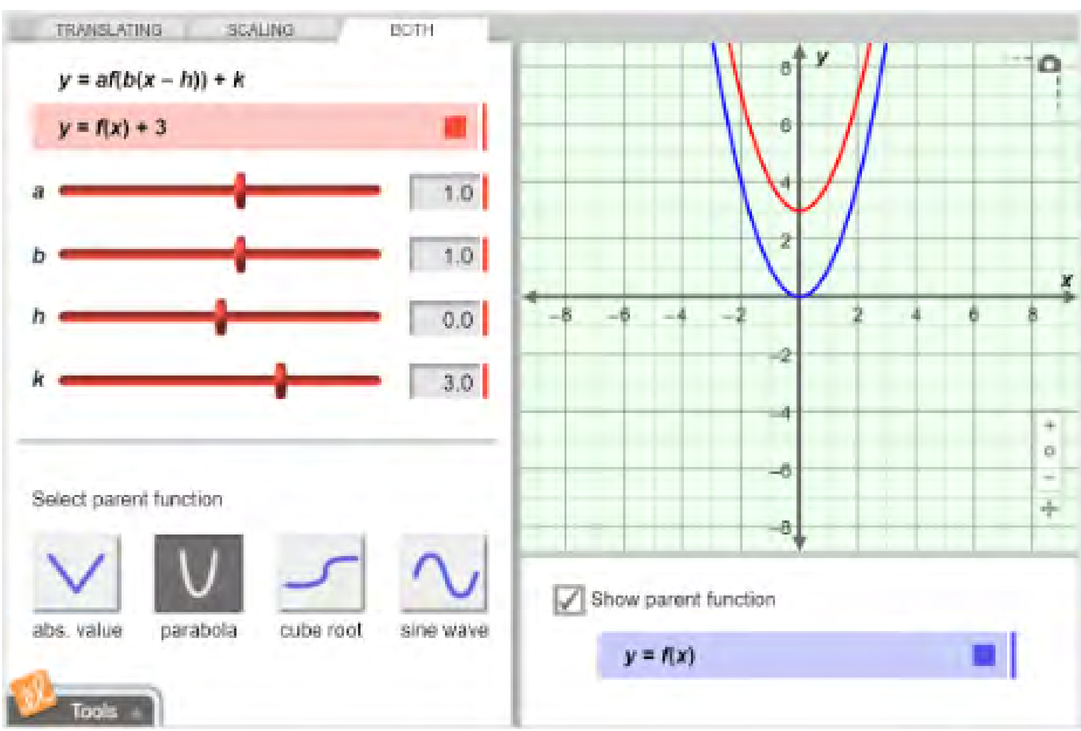
Generating and testing hypotheses about new knowledge results in an average percentile point gain of 37 (ES = 1.14).

SOURCE: Marzano (1998), p.106

Although computer-based manipulatives are powerful tools, students derive the greatest value from them when they are guided in their use. As noted by Clements & McMillen (1996), the full pedagogical power of the manipulative is achieved when students mindfully reflect on the actions they perform and how the manipulative responds to them.

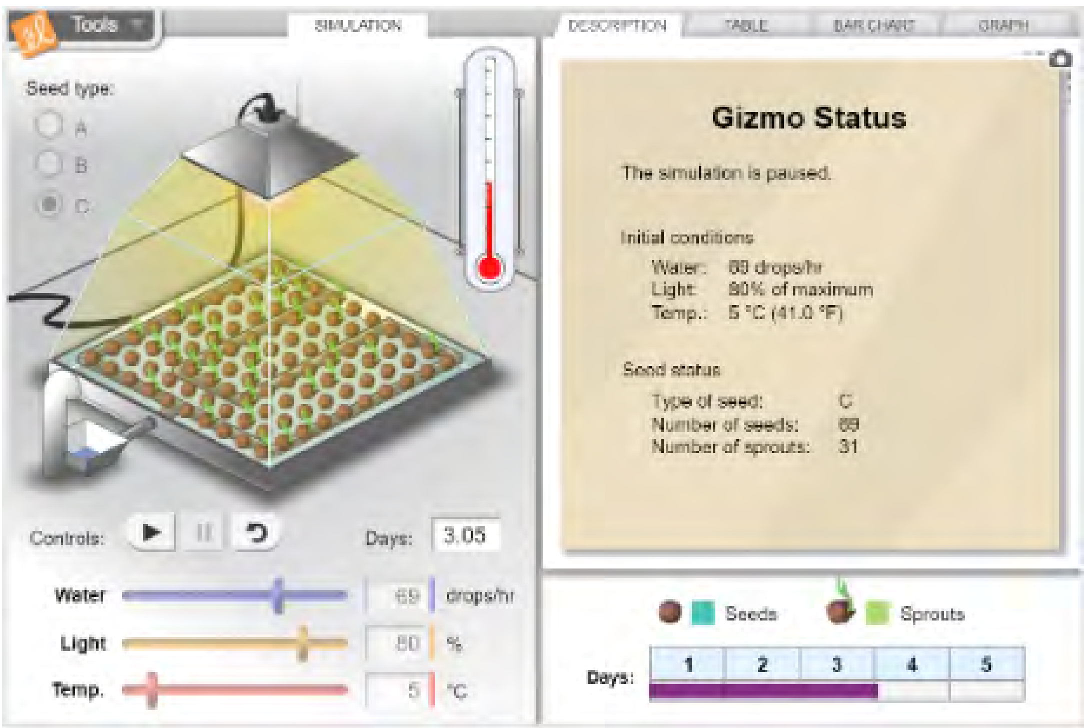
The Student Exploration Sheets that accompany every Gizmo are designed to support and stimulate this type of mindful interaction. Although the Exploration Sheets use different formats (depending on the nature of the associated Gizmo), they all provide a sequence of activities that guide students in using and thinking about the manipulative. These activities are followed by a set of assessment items that evaluate each student's progress. The Gizmos system automatically scores these assessments and provides teachers with online progress reports.

A typical Exploration Sheet starts with students engaging in a set of exercises where they perform specific actions and record the results. Then, they are prompted to make predictions about new situations, after which they verify their answers using the Gizmo. For example, in the Gizmo *Translating and Scaling Functions*, students first individually vary the *a*, *b*, *h* and *k* parameters in a function in form $y = af(b(x - h)) + k$. After observing the effects of increasing and decreasing these parameters, they are asked to predict how the graph of $y = f(x) + 3$ will differ from the graph of $y = f(x)$. The Gizmo is used to verify their prediction.



Gizmo: Translating and Scaling Functions

Other Student Exploration Sheets follow the format of typical science lab activities. In the *Seed Germination Gizmo*, for example, students are lead through a set of experiments where they vary the amount of water and light a group of seeds is exposed to, as well as the temperature of the seeds' incubator. Then, they observe the number of seeds that germinate into sprouts. In addition to learning about the effects the manipulated variables have on seed germination rates, students also develop firsthand experience with principles of experimental design – such as why scientists perform several trials of an experiment and then average the results, and how they isolate the effects of individual variables as well as study their combined impact. The Exploration Sheet highlights these important aspects of scientific inquiry, and guides students in evolving and refining their hypotheses through careful experimentation.



Gizmo: Seed Germination

Using Gizmos in conjunction with their associated Student Exploration Sheets, students can generate and test a very wide range of hypotheses quickly and safely, without the need to set up and configure any physical apparatus. Science Gizmos can also serve as invaluable preparatory tools before students perform lengthy experiments with real equipment in labs.

2.4 Direct presentation, followed by application

META-ANALYSIS RESEARCH SUMMARY: PRESENTATION FOLLOWED BY APPLICATION

Demonstrating new concepts to students in a direct fashion and then having them apply the concepts to different situations is an effective instructional sequence.

- Initial direct presentation of conceptual categories, generalizations, and principles is associated with an average percentile point gain of 49 (ES = 2.55).
- Having students apply conceptual categories, generalizations, and principles to new situations after being taught them is associated with an average percentile point gain of 38 (ES = 1.16).

SOURCE: Marzano (1998), p.106

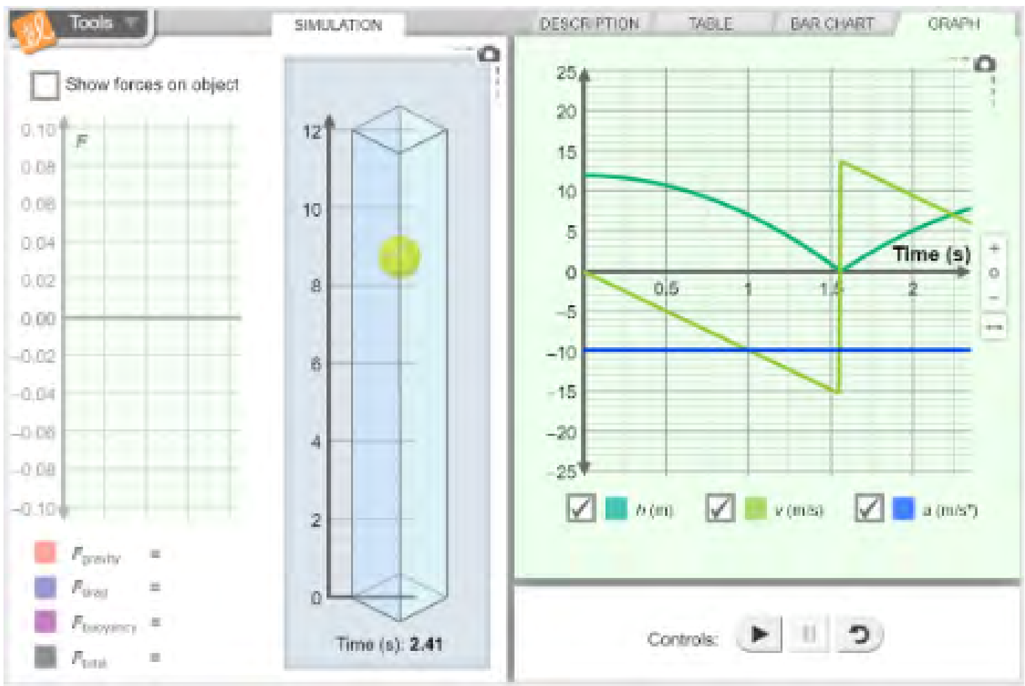
Although the Student Exploration Sheets that accompany all ExploreLearning Gizmos permit them to be used by students in a self-directed manner, this is not the only way in which Gizmos are designed to be used. As the Marzano (1998) meta-analysis notes, students learn effectively and efficiently when they are first taught new conceptual categories, generalizations, and principles directly, only after which they apply them on their own. Ideally, then, educational software should support this instructional sequence by serving two main objectives: first, it should support teachers in presenting new knowledge to students, and second, it should support students in applying and extending what they have learned on a more individual basis.

Most educational software products, however, are designed exclusively for use by individual students in extended tutorial-style one-on-one sessions, with no explicit role for the teacher. This kind of software is cumbersome or impossible to integrate directly into classroom teaching as a demonstration or explanation aid. As a result, these products provide little or no support to teachers when they are first introducing a topic to their students, or when they are trying to stimulate classroom discussion. Furthermore, when a set tutorial is integrated within the software, teachers cannot flexibly differentiate the level or focus of instruction for different groups of students.

ExploreLearning Gizmos, on the other hand, are highly modular and flexible. They are designed to fit the needs of a broad range of teachers and instructional settings, regardless of whether a classroom has a single computer connected to an overhead projector or whether there is one computer per student. Teachers can integrate Gizmos as presentation aids when they are first teaching a topic to their students, then use them to anchor and stimulate classroom discussions, and finally have students apply and practice new concepts and skills on their own through the Gizmo.

For example, using the [Gizmo Free-Fall Laboratory](), teachers can quickly discuss and demonstrate the effect of varying parameters in an experiment, and then have students make conjectures about the results:

1. The teacher tells her students that she is going to simulate a tennis ball dropping through a 12-meter tube containing a vacuum. She uses the *Free-Fall Laboratory Gizmo* (projected on a screen at the front of her class) to demonstrate this scenario and show the graphs of position, velocity and acceleration that result.
2. Next, she asks the students how the graphs might change if the tube was filled with air instead of a vacuum. She directs the students to sketch their ideas.
3. Using the Gizmo, she quickly performs a trial involving a 12-meter air-filled tube, and students compare the Gizmo's graphs to the ones they generated. The class discusses the results.
4. The class moves on to consider how the graphs would change if the object dropped was a shuttlecock rather than a tennis ball, or if the drop distance was shortened or lengthened.



[Gizmo: Free-Fall Laboratory]()

Teachers who already integrate demonstrations with physical objects into their teaching will find that Gizmos allow them to do a greater number of more varied demonstrations in the same amount of time. Teachers who are unaccustomed to incorporating demonstrations into their teaching will need to do a certain degree of preparation and planning before using Gizmos in this manner, as this will represent a departure from the presentation style that they are accustomed to. It is important to bear in mind, however, that the Student Exploration Sheets that accompany each Gizmo provide teachers with a very convenient way to add Gizmos to their lesson plans. The ready-made exercises and integrated assessment that the Exploration Sheets contain means that advance preparation is never required on the teacher's part. This ensures that all teachers can use Gizmos in their classrooms quickly and easily, and that students can benefit from these learning tools immediately. Over time, as Gizmos become more familiar instructional tools, teachers can begin to integrate them more fully into their own teaching styles, and thereby realize the full potential of this new form of interactive content.

3. Summary

Meta-analysis of the research literature has identified broad scientific evidence for the effectiveness of certain instructional techniques. ExploreLearning's comprehensive library of mathematics and science Gizmos brings these powerful instructional techniques to the classroom in a convenient, easy-to-use format that makes them practical and efficient as well as effective.

Instructional techniques that have been proven effective through meta-analysis

4. References

Clements, D.H., & McMillen, S. (1996). Rethinking concrete manipulatives. *Teaching children mathematics*, 2(5), 270-279.

Gerlic, I., & Jausovec, N. (1999). Multimedia: Differences in cognitive processes observed with EEG. *Educational Technology Research and Development*, 47(3), 5–14.

Marzano, R.J. (1998). *A theory-based meta-analysis of research on instruction*. Aurora, CO: Mid-continent Research for Education and Learning.

Marzano, R.J., Gaddy, B.B., & Dean, C. (2000). *What works in classroom instruction*. Aurora, CO: Mid-continent Research for Education and Learning.

National Governors Association Center for Best Practices, Council of Chief State School Officers. (2010). *Common Core State Standards for Mathematics*.
[Available at: http://www.corestandards.org/wp-content/uploads/Math_Standards1.pdf]

Neuman, S.B. (2002) *Welcome and introduction*. Washington, DC: Department of Education working group conference on the use of scientifically based research in education (February 6, 2002).

NGSS Lead States. (2017). *Next Generation Science Standards: For States, By States: DCI Arrangements of the Next Generation Science Standards*.
[Available at: https://www.nextgenscience.org/sites/default/files/AllDCI.pdf]

No Child Left Behind Act of 2001, Pub. L. No. 107-110 (2002).
[Available at: http://www.ed.gov/policy/elsec/leg/esea02/index.html]

Stanovich, P.J., & Stanovich, K.E. (2003). *Using Research and Reason in Education: How Teachers Can Use Scientifically-Based Research to Make Curricular & Instructional Decisions.* Portsmouth, NH: RMC Research Corp.

Complete List of ExploreLearning Gizmos

Updated Fall 2022

2D Collisions
2D Eclipse
3D and Orthographic Views
3D Eclipse

Absolute Value Equations and Inequalities
Absolute Value with Linear Functions
Adding and Subtracting Integers
Adding and Subtracting Integers with Chips
Adding Fractions (Fraction Tiles)
Adding on the Number Line
Adding Vectors
Adding Whole Numbers and Decimals (Base-10 Blocks)
Addition and Subtraction of Functions
Addition of Polynomials
Additive Colors
Advanced Circuits
Air Track
Animal Group Behavior (STEM Case)
Ants on a Slant (Inclined Plane)
Archimedes' Principle
Area of Parallelograms
Area of Triangles
Arithmetic and Geometric Sequences
Arithmetic Sequences
Atwood Machine
Average Atomic Mass

Balancing Blocks (Volume)
Balancing Chemical Equations
Basic Prism
Beam to Moon (Ratios and Proportions)
Beam to Moon (Ratios and Proportions) - metric
Biconditional Statements
Big Bang Theory - Hubble's Law
Binomial Probabilities
Bohr Model of Hydrogen
Bohr Model: Introduction
Box-and-Whisker Plots
Boyle's Law and Charles' Law
Building DNA
Building Pangaea
Building Topographic Maps

Calorimetry Lab
Cannonball Clowns (Number Line Estimation)
Carbon Cycle
Cargo Captain (Multi-digit Subtraction)
Cat and Mouse (Modeling with Linear Systems)
Cat and Mouse (Modeling with Linear Systems) - metric
Cell Division
Cell Energy Cycle
Cell Respiration (STEM Case)
Cell Structure
Cell Types
Center of Mass
Charge Launcher
Chemical and Physical Changes (STEM Case)
Chemical Changes
Chemical Equations
Chicken Genetics
Chocomatic (Multiplication, Arrays, and Area)
Chords and Arcs
Circles
Circuit Builder
Circuits
Circulatory System
Circumference and Area of Circles
City Tour (Coordinates)
Cladograms
Classifying Quadrilaterals
Classifying Triangles
Coastal Winds and Clouds
Coastal Winds and Clouds - metric
Colligative Properties
Collision Theory
Color Absorption
Comparing and Ordering Decimals
Comparing Climates (Customary)
Comparing Climates (Metric)
Comparing Earth and Venus
Compound Inequalities
Compound Interest
Concurrent Lines, Medians, and Altitudes
Conditional Statements
Conduction and Convection
Congruence in Right Triangles
Constructing Congruent Segments and Angles
Constructing Parallel and Perpendicular Lines
Convection Cells
Coral Reefs 1 - Abiotic Factors
Coral Reefs 2 - Biotic Factors

Correlation
Cosine Function
Coulomb Force (Static)
Covalent Bonds
Critter Count (Modeling Multiplication)
Crumple Zones

Dehydration Synthesis
Density
Density Experiment: Slice and Dice
Density Laboratory
Density via Comparison
Describing Data Using Statistics
Determining a Spring Constant
Determining Density via Water Displacement
Dichotomous Keys
Diffusion
Diffusion (STEM Case)
Digestive System
Dilations
Direct and Inverse Variation
Disease Spread
Distance Formula
Distance-Time and Velocity-Time Graphs
Distance-Time and Velocity-Time Graphs - Metric
Distance-Time Graphs
Distance-Time Graphs - Metric
Dividing Exponential Expressions
Dividing Fractions
Dividing Mixed Numbers
Dividing Polynomials Using Synthetic Division
DNA Analysis
DNA Profiling
Doppler Shift
Doppler Shift Advanced
Drug Dosage
Dye Elimination

Earthquake-Proof Homes
Earthquakes 1 - Recording Station
Earthquakes 2 - Determination of Epicenter
Eclipse
Ecosystems (STEM Case)
Effect of Environment on New Life Form
Elapsed Time
Electromagnetic Induction
Electron Configuration
Electrons and Chemical Reactions (STEM Case)
Element Builder

Elevator Operator (Line Graphs)
Ellipses
Embryo Development
Energy Conversion in a System
Energy Conversions
Energy of a Pendulum
Enzymes (STEM Case)
Equilibrium and Concentration
Equilibrium and Pressure
Equivalent Algebraic Expressions I
Equivalent Algebraic Expressions II
Equivalent Fractions (Fraction Tiles)
Erosion Rates
Estimating Population Size
Estimating Sums and Differences
Evolution (STEM Case)
Evolution: Mutation and Selection
Evolution: Natural and Artificial Selection
Exploring Linear Inequalities in One Variable
Exponential Functions
Exponential Growth and Decay
Exponents and Power Rules
Eyes and Vision 1 – Seeing Color
Eyes and Vision 2 – Focusing Light
Eyes and Vision 3 – Sensing Light

Factor Trees (Factoring Numbers)
Factoring Special Products
Fan Cart Physics
Fast Plants® 1 – Growth and Genetics
Fast Plants® 2 – Mystery Parent
Feed the Monkey (Projectile Motion)
Feel the Heat
Fido's Flower Bed (Perimeter and Area)
Finding Factors with Area Models
Finding Patterns
Fingerprinting
Flood and Storm-Proof Homes
Flower Pollination
Food Chain
Force and Fan Carts
Forest Ecosystem
Fraction Artist 1 (Area Models of Fractions)
Fraction Artist 2 (Area Models of Fractions)
Fraction Garden (Comparing Fractions)
Fraction, Decimal, Percent (Area and Grid Models)
Fractions Greater than One (Fraction Tiles)
Fractions with Unlike Denominators
Free Fall Tower

Free-Fall Laboratory
Freezing Point of Salt Water
Frog Dissection
Fruit Production (STEM Case)
Function Machines 1 (Functions and Tables)
Function Machines 2 (Functions, Tables, and Graphs)
Function Machines 3 (Functions and Problem Solving)

General Form of a Rational Function
Genetic Engineering
Geometric Probability
Geometric Sequences
Germination
GMOs and the Environment
Golf Range
Graphing Skills
Graphs of Derivative Functions
Graphs of Polynomial Functions
Gravitational Force
Gravity Pitch
Greenhouse Effect
Greenhouse Effect - metric
Growing Plants

Half-life
Hardy-Weinberg Equilibrium
Hearing: Frequency and Volume
Heat Absorption
Heat Transfer by Conduction
Heredity and Traits (STEM Case)
Herschel Experiment
Herschel Experiment - metric
Histograms
Holiday Snowflake Designer
Homeostasis
Homeostasis (STEM Case)
Honeybee Hive
Household Energy Usage
H-R Diagram
Human Evolution - Skull Analysis
Human Homeostasis
Human Karyotyping
Hurricane Motion
Hurricane Motion - metric
Hyperbolas

Ideal Gas Law
Identifying Nutrients
Improper Fractions and Mixed Numbers
Inclined Plane - Rolling Objects
Inclined Plane - Simple Machine
Inclined Plane - Sliding Objects
Independent and Dependent Events
Inheritance
Inscribed Angles
Integers, Opposites, and Absolute Values
Introduction to Exponential Functions
Introduction to Functions
Investigating Angle Theorems
Ionic Bonds
Isosceles and Equilateral Triangles
Isotopes

Laser Reflection
Least-Squares Best Fit Lines
Levers
Limiting Reactants
Linear Functions
Linear Inequalities in Two Variables
Linear Programming
Logarithmic Functions
Logarithmic Functions: Translating and Scaling
Longitudinal Waves
Lucky Duck (Expected Value)

Magnetic Induction
Magnetism
Mascot Election (Pictographs and Bar Graphs)
Mean, Median, and Mode
Measuring Motion
Measuring Trees
Measuring Volume
Meiosis
Melting Points
Meowsis (STEM Case)
Microevolution
Mineral Identification
Modeling and Solving Two-Step Equations
Modeling Decimals (Area and Grid Models)
Modeling Fractions (Area Models)
Modeling One-Step Equations
Modeling the Factorization of ax2+bx+c
Modeling the Factorization of x2+bx+c
Modeling Whole Numbers and Decimals (Base-10 Blocks)
Moles
Moment of Inertia
Moonrise, Moonset, and Phases
Mouse Genetics (One Trait)

Mouse Genetics (Two Traits)
Movie Reviewer (Mean and Median)
Multiplying Decimals (Area Model)
Multiplying Exponential Expressions
Multiplying Fractions
Multiplying Mixed Numbers
Multiplying with Decimals
Muscles and Bones
Mystery Powder Analysis

Natural Selection
Nitrogen Cycle (STEM Case)
No Alien Left Behind (Division with Remainders)
Nuclear Decay
Nuclear Reactions
Number Line Frog Hop (Addition and Subtraction)
Number Systems

Observing Weather (Customary)
Observing Weather (Metric)
Ocean Carbon Equilibrium (STEM Case)
Ocean Mapping
Ocean Tides
Operations with Radical Expressions
Orbital Motion - Kepler's Laws
Order of Operations
Ordering and Approximating Square Roots
Ordering Percents, Fractions, and Decimals Greater Than 1
Osmosis
Osmosis (STEM Case)

Parabolas
Parallel, Intersecting, and Skew Lines
Parallelogram Conditions
Paramecium Homeostasis
Part-to-part and Part-to-whole Ratios
Pattern Finder
Pattern Flip (Patterns)
Pendulum Clock
Penumbra Effect
Percent of Change
Percents and Proportions
Percents, Fractions, and Decimals
Perimeter and Area of Rectangles
Perimeters and Areas of Similar Figures
Period of a Pendulum
Period of Mass on a Spring
Periodic Trends
Permutations and Combinations
pH Analysis
pH Analysis: Quad Color Indicator
Phase Changes
Phased Array
Phases of the Moon
Phases of Water
Photoelectric Effect
Photosynthesis (STEM Case)
Photosynthesis Lab
Pith Ball Lab
Plants and Snails
Plate Tectonics
Points in the Complex Plane
Points in the Coordinate Plane
Points, Lines, and Equations
Point-Slope Form of a Line
Polarity and Intermolecular Forces
Pollination: Flower to Fruit
Polling: City
Polling: Neighborhood
Polygon Angle Sum
Polynomials and Linear Factors
Pond Ecosystem
Populations and Samples
Porosity
Potential Energy on Shelves
Prairie Ecosystem
Prisms and Cylinders
Probability Simulations
Programmable Rover
Properties of Matter (STEM Case)
Proportions and Common Multipliers
Protein Synthesis (STEM Case)
Proving Triangles Congruent
Pulley Lab
Pulleys
Pyramids and Cones
Pythagorean Theorem
Pythagorean Theorem with a Geoboard

Quadratic Inequalities
Quadratics in Factored Form
Quadratics in Polynomial Form
Quadratics in Vertex Form
Quilting Bee (Symmetry)

Rabbit Population by Season
Radians
Radiation

Radical Functions
Rainfall and Bird Beaks
Rainfall and Bird Beaks - metric
Rational Functions
Rational Numbers, Opposites, and Absolute Values
Ray Tracing (Lenses)
Ray Tracing (Mirrors)
Reaction Energy
Reaction Time 1 (Graphs and Statistics)
Reaction Time 2 (Graphs and Statistics)
Reading Topographic Maps
Real-Time Histogram
Reflections
Refraction
Relative Humidity
Reverse the Field
Riemann Sum
Ripple Tank
River Erosion
RNA and Protein Synthesis
Road Trip (Problem Solving)
Rock Art (Transformations)
Rock Classification
Rock Cycle
Roller Coaster Physics
Roots of a Quadratic
Rotations, Reflections, and Translations
Rounding Whole Numbers (Number Line)

Seasons Around the World
Seasons in 3D
Seasons: Earth, Moon, and Sun
Seasons: Why do we have them?
Seed Germination
Segment and Angle Bisectors
Senses
Sight vs. Sound Reactions
Similar Figures
Similarity in Right Triangles
Simple Harmonic Motion
Simplifying Algebraic Expressions I
Simplifying Algebraic Expressions II
Simplifying Radical Expressions
Simplifying Trigonometric Expressions
Sine Function
Sine, Cosine, and Tangent Ratios
Sled Wars
Slope
Slope-Intercept Form of a Line
Solar System
Solar System Explorer
Solubility and Temperature
Solving Algebraic Equations I
Solving Algebraic Equations II
Solving Equations by Graphing Each Side
Solving Equations on the Number Line
Solving Formulas for any Variable
Solving Linear Inequalities in One Variable
Solving Linear Systems (Matrices and Special Solutions)
Solving Linear Systems (Slope-Intercept Form)
Solving Linear Systems (Standard Form)
Solving Two-Step Equations
Solving Using Trend Lines
Sound Beats and Sine Waves
Special Parallelograms
Spin the Big Wheel! (Probability)
Square Roots
Standard Form of a Line
Star Spectra
Stem-and-Leaf Plots
Sticky Molecules
Stoichiometry
Subtracting Whole Numbers and Decimals (Base-10 Blocks)
Subtractive Colors
Sum and Difference Identities for Sine and Cosine
Summer and Winter
Sums and Differences with Decimals
Surface and Lateral Areas of Prisms and Cylinders
Surface and Lateral Areas of Pyramids and Cones
Systems of Linear Inequalities (Slope-intercept form)

Tangent Function
Target Sum Card Game (Multi-digit Addition)
Temperature and Particle Motion
Temperature and Sex Determination
Temperature and Sex Determination - Metric
Theoretical and Experimental Probability
Tides
Tides - metric
Time Estimation
Titration
Torque and Moment of Inertia
Toy Factory (Set Models of Fractions)
Translating and Scaling Functions
Translating and Scaling Sine and Cosine Functions
Translations
Treasure Hunter (Decimals on the Number Line)
Trebuchet