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.

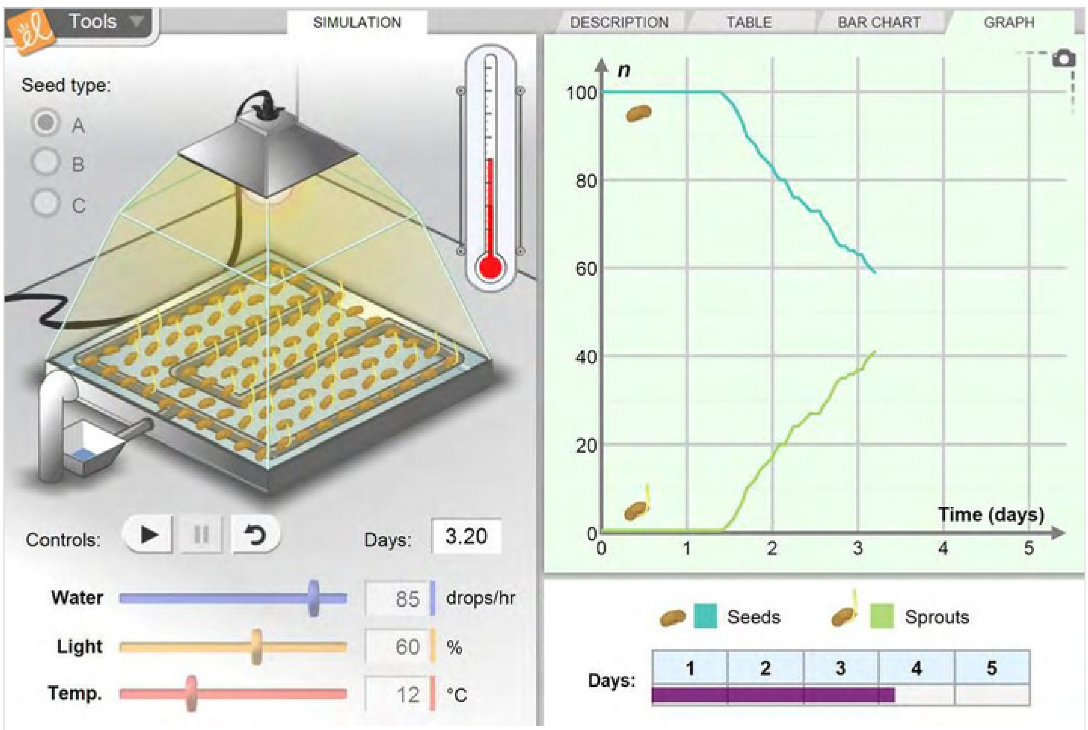
2.3 Supporting application of new knowledge

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).

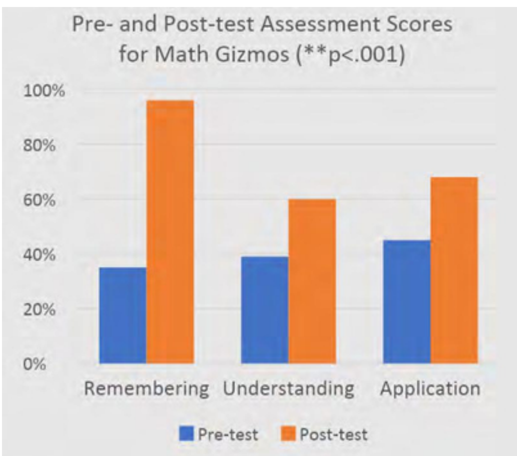
An RCT (randomized, controlled trial) by the Maine Department of Education evaluated the impact of a a technology-centered two-year professional development program, which involved incorporating *Gizmos* into mathematics instruction, across 56 rural middle schools. At post-test, ***their students significantly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

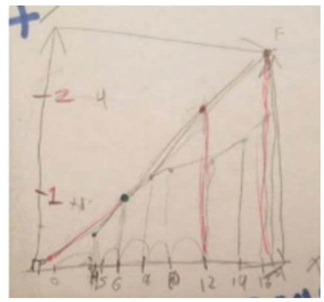


Figure 2:
M’s correct representation at post-test

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

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