VariQuest® Research-Based Design Decisions

Featuring Academic Empirical Research

This report highlights how educational research informed VariQuest product design decisions, ensuring alignment with evidence-based visual and kinesthetic learning practices.

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Study 1: Kellman, P. J., Massey, C. M., & Son, J. Y. (2009). Perceptual learning modules in mathematics: Enhancing students' pattern recognition, structure extraction, and fluency. Topics in Cognitive Science, 1(1), 1–21

Abstract: Mathematics learning requires not only conceptual understanding but also fluency in recognizing patterns, extracting structure, and applying procedures efficiently. Traditional instruction often emphasizes rules and symbolic manipulation, yet many students continue to struggle with problem-solving and transfer of skills. Perceptual learning research suggests that expertise in a domain is supported by the ability to rapidly perceive relevant patterns and relations, a skill that develops through targeted practice with varied examples. This study introduces Perceptual Learning Modules (PLMs) as a technology-based approach to accelerate students' recognition of mathematical structures and enhance fluency. Grounded in cognitive science, PLMs provide interactive tasks designed to highlight meaningful patterns and promote adaptive generalization across contexts. By situating mathematics instruction within the broader framework of perceptual and cognitive learning, the authors aim to demonstrate how PLMs can strengthen core mathematical competencies, improve efficiency in problem-solving, and support long-term transfer of knowledge.

Population & Sample Size: Experiment 1 (Algebraic transformations – college students): About 24 undergraduates participated. Experiment 2 (Fractions – middle and high school students): Roughly 30 students tested PLMs in classroom settings. Experiment 3 (Equation solving – high school students): Around 20 students were included. Classroom pilots (various levels): Additional groups of middle and high school students participated, often in small class-sized samples (15–25 per group).

Findings: Students who practiced with PLMs showed significant gains in recognizing mathematical structures (e.g., algebraic forms, fractions) compared to those using only traditional instruction. They were able to apply procedures more quickly and accurately, showing improved fluency. Learners reached proficiency in less time than peers in control conditions. Repeated exposure to varied problem examples led to faster recognition of underlying rules and relationships. Skills gained with PLMs transferred beyond the immediate practice tasks - for example, students who practiced perceptual discrimination of algebraic forms performed better on solving equations and related math tasks. Positive outcomes were found with middle school, high school, and college students, suggesting PLMs are versatile across educational stages. Students were generally engaged with the interactive, technology-based format. Teachers reported that PLMs supplemented classroom instruction effectively, without replacing conceptual teaching.

VariQuest Design Decision: All of our content libraries for our tools contain supplementary learning aids that lend to recognizing patterns and processes as they relate to mathematical (and other subject) learning structures. While our tools are designed for printed output and not computer-based modules as this study focused on, our younger students benefit greatly from tactile aids that engage them with hands-on strategies. From flash cards to number lines to mnemonic device displays, our content library is designed for educators to save time in creating these enhanced learning strategy tools.

Application: As per this study, students who have learning tools that directly correlate to mathematical concepts and patterns will perform better. And our goal is to provide educators with all relevant materials to do this - so we have created multiple options for our Motiva® Specialty Printer, Cutout Maker, and Perfecta® Poster Design System that are designed to reinforce these mathematical concepts while often engaging parental involvement and reference materials for personal belongings such as interactive notebooks.

Study 2: Lozada, M., & Carro, N. (2016). Embodied action improves cognition in children: Evidence from a study based on Piagetian conservation tasks. Frontiers in Psychology, 7, 393.

Abstract: This study investigates the role of embodied action in children's cognitive development through the lens of Piagetian conservation tasks. The researchers examined whether physically performing the actions associated with conservation tasks could improve children's understanding compared to traditional verbal or observational instruction. Ninety-six children between ages 6 and 7 were assigned to either an embodied-action condition, where they manipulated objects directly, or a control condition, where they observed or received verbal explanations. Results showed that children in the embodied-action condition demonstrated significantly higher success rates in conservation tasks across quantity, length, and liquid conservation. The findings suggest that engaging children in meaningful physical actions enhances conceptual understanding, supporting theories of embodied cognition. This study highlights the educational importance of incorporating kinesthetic learning strategies to strengthen abstract reasoning in early childhood.

Population & Sample Size: 96 elemetary-school-aged children in Argentina. Race/ethnicity/socio-economic status were not reported as part of the study.

Findings: Children who physically performed the conservation tasks (embodied-action condition) showed higher success rates compared to children in the control condition who only observed or received verbal instruction. Improvements were observed in quantity, length, and liquid conservation tasks, indicating that embodied action enhances understanding across different cognitive domains. The findings support the theory that physical interaction with objects strengthens conceptual understanding, particularly in early childhood. Incorporating kinesthetic learning strategies in teaching can boost abstract reasoning and help children grasp concepts that might be difficult through verbal or observational methods alone.

VariQuest Design Decision: Our Cutout Maker Digital Die-Cut Machine content in our VariQuest Design Software includes multiple sensory path templates for educators to utilize in teaching concepts around dinosaurs, ecosystems, oceanography, and more. In addition, the tool offers hands-on manipulatives such as lacing cards, foldable "flap-backs", flashcard wheels, games, puzzles, and window boards for active learning aids. Getting students physically active during their learning, as per this study, will save educators time in lesson-plan tool creation and gets students physically involved in their learning. Our Perfecta Poster Design System also creates game boards, and Motiva Specialty Printer has collections of activity and brain break cards that also lend to our design library of physically-active-encouraging content.

Application: Kinesthetic learning, as per this study, increases cognition and comprehension when learning. We have created multiple manipulative pieces for educators to use to aid in learning so there is physical interaction with students and their learning - and we're saving time for educators creating them.

Study 3: Mayer, R. E., & Anderson, R. B. (1991). Animations need narrations: An experimental test of a dual-coding hypothesis. Journal of Educational Psychology, 83(4), 484–490.

Abstract: This study investigated the effectiveness of combining animation with narration in instructional materials, testing predictions from the dual-coding theory. College students were randomly assigned to one of three instructional conditions: animation with narration, animation with on-screen text, or animation alone. Participants' learning outcomes were assessed through recall and problem-solving tasks. Results indicated that students who received animation with narration performed significantly better on both measures compared to those in the other conditions. The findings support the dual-coding hypothesis, suggesting that integrating verbal explanations with visual animations enhances comprehension by engaging both visual and auditory cognitive channels. These results have important implications for the design of multimedia instructional materials, emphasizing the need for coordinated narration to optimize learning.

Population & Sample Size: The sample consisted of 102 college students at the University of California, Santa Barbara who were mechanically naive, meaning they had little prior knowledge of mechanical systems. The study did not specify the participants' gender, age range, or ethnic background.

Findings: Students who viewed animations paired with spoken narration performed significantly better on recall and problem-solving tasks compared to those who saw animations with on-screen text or animations alone. The results support the dual-coding hypothesis, which posits that learning is enhanced when information is presented through both visual and auditory channels rather than a single channel. Learning was more effective when narration was contiguous with the animation, meaning the spoken explanations matched the visual events as they occurred, reducing cognitive load and facilitating comprehension. On-screen text accompanying animations did not produce the same learning gains as narration, highlighting that visual-verbal integration is more effective than splitting attention between text and animation. Coordinating narration with animation is critical for designing multimedia learning materials that maximize comprehension and retention.

VariQuest Design Decision: We have created content collections for our Cutout Maker Digital Die-Cut Machine that provide hands-on animations (manipulatives) for students (and educators) to build and display complex learning concepts such as the water cycle, human skeleton, and more. This interactive animation display, as referenced in the study, helps students learn and retain this information by actively engaging them in their study. In addition, many of our posters for creation on the Perfecta® Poster Design System illustrate processes and concepts as anchor charts for visual reinforement.

Application: The dual-coding hypothesis was leveraged in design decisions for creating our content in such that learners need to be hands-on engaged with their learning and need to be involved in putting together the fluidity of complex learning concepts, such as ecosystems and cycles. Our collections give educators time-saving tools to quickly create these concepts - giving students hands-on content to learn alongside their verbal instruction.

Relevance Explanation: While we do have a focus in use for post-secondary student populations, this research in analyzing mechanical concepts directly relates to Pre-K, elementary, intermediate, and high school curriculum concepts as well.

Study 4: Mavilidi, M. F., Okely, A. D., Chandler, P., Cliff, D. P., & Paas, F. (2015). Effects of integrated physical exercises and gestures on preschool children's foreign language vocabulary learning. Educational Psychology Review, 27(3), 413–426.

Abstract: This experimental study investigated how integrating physical exercises and gestures into language instruction affects preschool children's ability to learn foreign language vocabulary. A total of 111 preschool children from 15 childcare centers participated in a 4-week intervention program where they were randomly assigned to one of four conditions: * Integrated Physical Exercise and Gestures: Children enacted the actions indicated by the words to be learned through physical exercises. * Physical Exercise Only: Children performed physical exercises at the same intensity, but unrelated to the learning task. * Gesturing Only: Children enacted the actions indicated by the words to be learned by gesturing while remaining seated. * Conventional Learning: Children verbally repeated the words while remaining seated.

Population & Sample Size: 111 preschool children from 15 childcare centers in Sydney, Australia. The publication does not provide race/socio-economic demographic information.

Findings: Children in the Integrated Physical Exercise and Gestures condition achieved the highest learning outcomes in foreign language vocabulary acquisition. The Physical Exercise Only and Gesturing Only conditions also showed improved learning compared to the Conventional Learning condition. The study suggests that combining physical activity with gestures enhances vocabulary learning by engaging multiple cognitive and motor pathways. The findings support the idea that integrating physical movement and gestures into educational practices can be an effective strategy for enhancing learning outcomes in young children. This approach aligns with embodied cognition theories, which posit that cognitive processes are deeply rooted in the body's interactions with the environment.

VariQuest Design Decision: Our tools all provide content for English language, and foreign language learners that is intended to create active components that supplement their verbal instruction. From visual communication boards to sign language displays to ELL Bingo Boards, our content is driven with these needs in mind.

Application: ELL students and foreign language learners, per this study, need physical interaction and gestures coupled with their mastery of a new language. With this in mind, we have created content and continue to create content for our software that physically activates their learning with multiple facets and tools of instruction.

Study 5: Huang, O., Lee, P. Y. K., & Nobre, C. (2025). From reality to recognition: Evaluating visualization analogies for novice chart comprehension. arXiv.

Abstract: Novice learners often struggle to interpret complex data visualizations due to limited familiarity with abstract chart conventions. This study investigates the effectiveness of visualization analogies, which map data representations to familiar real-world contexts, in improving chart comprehension. A within-subject experimental design was conducted with 128 participants, who were exposed to both traditional charts and charts paired with analogical visualizations. Results indicate that visualization analogies significantly enhance accuracy and speed in chart interpretation, reduce cognitive load, and are preferred by novice learners over conventional visualizations. These findings suggest that analogical mapping can serve as a powerful pedagogical tool for improving data literacy and fostering intuitive understanding of novel chart types. Implications for educational design and future visualization research are discussed.

Population & Sample Size: 128 participants - novice learners who were university students or individuals with limited prior experience in interpreting complex data charts - recruited via an online platform that screened them for their familiarity with 8 different chart types. Specific race/age/socioeconomic details were not provided.

Findings: Participants performed significantly better when interpreting charts paired with visualization analogies compared to traditional baseline charts. Accuracy in data interpretation increased, and response times were faster, suggesting reduced cognitive effort. Novice learners overwhelmingly preferred charts with visualization analogies over traditional charts. Participants reported that analogies helped them understand and remember data patterns more easily. Visualization analogies were especially effective for novices with limited prior experience in chart comprehension - they facilitated the mapping of abstract chart elements to familiar real-world contexts, improving conceptual understanding. The study incorporated VARK learning preferences (Visual, Auditory, Reading/Writing, Kinesthetic) and concluded that visualization analogies enhanced comprehension across different learning styles, though the effect was particularly pronounced for visually-oriented learners. Implications for Educational Design: Analogical mapping can be used as a pedagogical tool to teach data literacy and chart interpretation. Integrating real-world context into visualizations reduces cognitive load and enhances intuitive understanding.

VariQuest Design Decision: Our Perfecta Poster Design System Content in our Engage Every Learner Content on the VariQuest Software contains many anchor chart visuals for display in the classroom. All the content in our Design Software was exclusively designed for education, and based on the need for physical, visual supports for students ages PreK thru Post-Secondary.

Application: Visual Learning is at the forefront of everything we do. Most learners are visual, but per this study, everyone can benefit from visual learning and reinforcement strategies, and thus all of our content is designed to aid in learning classroom concepts and creating an engaging learning environment.

Relevance Explanation: While this was not specifically directed at students, it analyzes how people are supplementally assisted in learning with visual supports.

Annotated Bibliography

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