Language Proficiency Influences Math Achievement

Embodiment in Mathematics Teaching and Learning

Stratification in Higher Education

Game-Based Assessment: Capturing Evidence of Learning in Play

Why do students like video games? Well-designed games reward players for mastering required content and strategies. They facilitate players’ advancement toward more complex activities, engage players in organized social interaction toward shared goals, and allow players to monitor their progress. Could video games be used to assess student achievement?

UW–Madison education professor Richard Halverson believes that learning scientists and assessment designers can, and should, develop methods for using games to assess student progress. Current assessment methods in classrooms often lack the motivating and information-rich ways that games capture data about learning. Game play can provide a powerful new form of assessment.

Halverson and colleagues Elizabeth Owen, Nathan Wills, and Benjamin Shapiro build video games based on cutting-edge science research, then capture game-play data as evidence of player learning. Their game-based assessment (GBA) project at the UW-Madison’s Games+Learning+Society (GLS) Research Center is funded by the National Science Foundation and directed by Halverson and Kurt Squire.

Game-Based Assessment Model

GLS games are designed to promote learning by involving players in worlds that explore regenerative biology, virology, medical technology and limnology. In the game Progenitor X (see image above), players cultivate stem cells to replace diseased tissues and organs. They guide viruses into cells in the game Virulent and explore how implicit bias influences perceptions in professional settings in the game Fair Play.

The flow of each game encourages players to navigate the norms, roles, and the narrative structure of a simulated world. The GLS design team brings together content experts, game developers and programmers, artists, educators, and learning scientists in a collaborative process to create games around specific learning goals. The team identifies subject matter that can be best expressed in a particular video game to enhance the players’ understanding of a particular education topic.

A GLS game consists of several chunks of content arranged according to current practice in a given domain. The content model for the game Progenitor X focuses on the processes scientists use to manipulate stem cells in the lab and use them in treatment. Such basic science questions are often overlooked in public discussion. It’s possible that game-based experience with the science of stem cells could encourage young players to consider this kind of research as a career option, and may enhance the public understanding of the science.

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Students are learning in virtual worlds that explore regenerative biology, virology, medical technology and limnology. Richard Halverson and colleagues discuss how to measure student learning as they play games like *Progenitor X*, in which players cultivate stem cells to replace diseased tissues and organs; the game *Virulent*, where students guide viruses into cells; and *Fair Play*, where students explore how implicit bias influences people’s perceptions in professional settings.

We use gestures in conversation, both to help us explain things, and to help listeners understand the point we’re trying to make. Martha Alibali and Mitchell Nathan argue that students’ understanding of mathematics can be improved when we know more about the gestures that teachers and learners produce during their explanations. Explanations provide a rich source of gesture data as students and teachers discuss equations, algebraic and geometric concepts, and word problems.

Researchers H. Gary Cook and Rosalie Grant find that helping English language learners (ELLs) with language proficiency helps raise their mathematics achievement. They find that ELLs’ scores on an academic English language proficiency assessment (ACCESS for ELLs®) can be significant predictors of their scores in mathematics on large-scale content assessments for third to eighth grades.

Over the decades, opportunities have expanded for U.S. high school graduates who seek higher education. They can choose among community colleges, 2-year campuses, 4-year public institutions, and online courses. The structure of higher education has been transformed as it has expanded. Although this expanding pie preserves relative advantages for the few, my colleagues and I have found evidence of increasing inclusiveness. That’s because expansion of access extends a valued good to a broader spectrum of the population and serves as an equalizing force.

A design team first determines the relation between the subject matter content and the flow of the game to understand whether players can access chunks of content through game play. Game designers test beta versions of games with student players. They collect data from students’ mouse clicks and look for patterns, as in education data mining. Game designers then develop records of in-game player interaction that are then used as evidence of learning.

GLS includes cycles of formative assessment, which provide ongoing feedback to game players. Games customize difficulty levels to match and challenge each student’s ability. A good game balances this ongoing assessment with a compelling story line and engaging adventures.

Good games also inspire communities of practice. They amplify in-game learning by fostering collective intelligence and participatory cultures.

To bring out the full potential of games for learning means that “little g” games, such as *Progenitor X*, should be nested in “big G” game contexts that activate play-based learning in social- and knowledge-rich interactions.

Halverson says the guiding question of the GBA design was to determine whether we could say anything interesting about learning with structured in-game data. Good games translate the educational content to the player through compelling challenges and strategies, while poor games allow players to bypass the content by simply pressing buttons and “gaming” the environment. The GLS Game-Based Assessment group’s early research can document the differences between players who are fooling around with the game and players who are trying to learn the science practices embedded in the game design.

These kinds of distinctions will help games researchers to show how games can serve as assessments that generate reliable evidence for content learning to formal education environments. The GLS group is partnering with the Learning Games Network and developers across the country to build game-based assessment tools into a new generation of learning games.

When that happens, Halverson says, we’ll liberate the potential of games—as the ultimate disruptive technology!—to shake and rattle the social conventions that limit the potential of learning technologies in schools.


Language proficiency influences mathematics achievement

For an increasing number of students, success in mathematics depends on English language proficiency.

And it’s not just proficiency in the vocabulary of mathematics itself that influences achievement. Student success relates to proficiency in academic languages of other content areas, social and instructional language, and skills in general writing, technical writing, speaking, and reading and listening.

World-Class Instructional Design and Assessment (WIDA) researchers H. Gary Cook and Rosalie Grant find that helping English language learners (ELLs) with language proficiency helps raise their mathematics achievement. Based at WCER, WIDA (www.wida.us) advances academic language development and achievement for linguistically diverse students. WIDA staff produces and distribute high quality standards, assessments, research, and professional development for educators.

Cook and Grant found that ELLs’ scores on an academic English language proficiency assessment (ACCESS for ELLs®) are significant predictors of their scores in mathematics on large-scale content assessments for third to eighth grades. They reached this conclusion in collaboration with Aek Phakiti, University of Sydney.

ACCESS for ELLs® (http://www.wida.us/assessment/ACCESS/) is WIDA’s English language proficiency assessment given to K–12 students who have been identified as ELLs. It is given annually in WIDA Consortium member states to monitor students’ progress in acquiring academic English. The new finding suggests that teaching language is another tool for teachers to support ELLs in mathematics.

This finding may reflect the increasing complexity of academic languages and greater demands placed on ELLs’ language proficiency as they are required to demonstrate knowledge and understanding of more complex mathematical concepts and processes in state tests.

To illustrate this relationship, Cook and Grant refer to what they call a “language construct” that influences students’ mathematics achievement (Figure 1).
Cook and Grant argue that this language construct may result from at least three conditions:

- One, it may be capturing components of academic language proficiency influenced by student characteristics and competencies, the degree of cognitive engagement, instructional supports, the linguistic complexity of tasks, and instructional contexts.
- Two, the construct may be capturing more general language characteristics, such as students’ strategic competence or other cognitive strategies that underpin performance on mathematics tests more broadly, or
- Three, the construct may be an artifact of the way in which ACCESS for ELLs® and mathematics tests are constructed. Another way of illustrating Cook and Grant’s finding is shown in Figure 2.

The two figures highlight the interconnectedness of proficiency in academic languages, social and instructional language, the language domains, and performance on written mathematics tests. Cook and Grant caution that their results apply to one content area—mathematics—in two states and, in one state with students from two years. Care should be taken to not generalize the models to other populations and other curriculum areas.

Embodiment in mathematics teaching and learning: Evidence from teachers’ and learners’ gestures

A hunter boasts how she bagged a ten-point buck by pantomiming the dramatic events leading to the kill.

A mechanic explains the $1,000 worth of repair to your car using hand gestures to illustrate the work he did.

In each case the gestures intensify the communication by reproducing actions commonly performed—viewing through binoculars, raising a rifle, lifting a car hood, turning a key, listening to an engine crank to life.

When explaining ourselves we often gesture without even thinking about it.

That’s because motor and perceptual simulations underlie our language and our imagery. We gesture to help communicate abstract ideas too. Just watch teachers and students in a math classroom. Professors Martha Alibali and Mitchell Nathan have.

They study how and why teachers and students use gestures to communicate mathematical concepts. From their perspective, mathematical knowledge doesn’t just reside in the mind. It’s embodied.

Why is it important to know that mathematical knowledge is embodied? Nathan and Alibali say it’s essential for understanding and improving mathematics performance, instruction, assessment, and learning.

Appreciating the embodied nature of mathematical thinking can help teachers (and researchers) understand why students find certain mathematics problems more difficult than others, identify suitable assessments to measure students’ mathematical knowledge, design more effective learning environments, select appropriate ways to teach mathematics content, and understand why some instructional methods work better than others.

Gestures both facilitate speakers’ language production and promote listeners’ comprehension. Alibali and Nathan focus on the gestures that mathematics teachers and learners produce in explanations. That includes teachers’ instructional explanations and learners’ explanations of their thinking.

This diagram shows the language construct (right) as the foundation that influences general and technical language skills. These skills include receptive and productive skills, which subsequently influence mathematics achievement.
Explanations provide a rich source of gesture data as students and teachers discuss equations, algebraic and geometric concepts, and word problems.

Alibali and Nathan explain that we use pointing gestures when thinking is grounded in the physical environment, representational gestures to communicate mental simulations of action and perception, and metaphoric gestures to communicate body-based concepts.

**Pointing gestures** indicate that the environment is an integral part of the cognitive system.

Mathematics teachers and learners use pointing gestures to link abstract mathematical ideas to the physical world, highlight corresponding aspects of related representations, and index the referents of their speech in talk about mathematical ideas.

Instructional pointing gestures seem to affect learners’ uptake of lesson content. For example, kindergarten students learning about symmetry succeeded on more than twice as many test items after a lesson that included pointing gestures than they did after a comparable lesson that did not include pointing gestures.

**Representational gestures** show the motoric and perceptual simulations that underlie language and imagery. These gestures manifest mental simulations of action and perception, facilitate thinking or speaking by activating mental images, help speakers package ideas into units suitable for speaking, and contribute to listener comprehension.

Evidence suggests that explaining mathematical thinking involves simulating performing actions on mathematical objects, visual images of mathematical ideas (often mental images of inscriptions), and real-world situations that mathematical problems address.

Speakers produce these gestures to facilitate thinking about mathematical ideas or to promote effective communication about such ideas.

**Metaphoric gestures** are a subclass of representational gestures. Some metaphoric gestures reflect concepts that are grounded in the body. These gestures suggest that thinking is based in the body. They also demonstrate that bodily resources enable “offline” thinking about objects, events, and relations not immediately present.

Metaphoric gestures often involve action and space. For example, two metaphors are “numbers are locations in space” (e.g., approaching zero) and “arithmetic is collecting objects” (e.g., put two and two together). Metaphors that involve space and action are readily expressed in gestures that reflect the spatial structure of the underlying images.

**Implications for research in the learning sciences**

The “embodied thinking” perspective aligns with two themes central to contemporary research in the learning sciences. The first is the attempt to bridge the divide between research and practice. The second is the importance of analyzing teaching and learning in authentic settings.

The embodied perspective acknowledges the complexities of learning and teaching in real-world settings. It provides a framework for analyzing the action and communication that take place in such settings in an effort to better understand processes of knowledge change.

**The embodied thinking perspective**

Our thinking and speaking processes are rooted in our perceptual and physical interactions with the world. The possibilities and limitations of our bodies shape these processes.

Thinking and communicating about mathematics involves abstract and imaginary entities. But even mathematical thinking is embodied. It is based in our perceptions and actions, and it is grounded in the physical environment.

Pointing gestures reflect the grounding of thinking in the physical or imagined environment.

Representational gestures simulate action and perception. The purpose of perception is to guide action, and actions are necessary in order to perceive.

Metaphoric gestures reveal the metaphoric structuring of concepts. As with pointing and representational gestures, conceptual metaphors are grounded in the body.

More about Alibali’s work: http://glial.psych.wisc.edu/index.php/psychsplashfacstaff/90

More about Nathan’s work: http://website.education.wisc.edu/~mnathan/Home.html
More than ever before, students have a variety of ways to benefit from higher education.

High school graduates who seek further education have a choice of community colleges, 2-year campuses, online courses, 4-year public institutions and, for the very few, private colleges and universities.

UW–Madison professor of education and sociology Adam Gamoran studies expansion of access to higher education. He has found that the structure of higher education has been transformed as it has expanded.

In the United States and other economically advanced countries, expansion of access has been accompanied by differentiation. National systems that had consisted almost exclusively of research universities have developed second-tier and less-selective colleges. Much of the growth in student enrollment has been absorbed by these second-tier institutions.

Yet at the same time that students from the working class found new opportunities to enroll in higher education, the system was being hierarchically differentiated, which means that these new opportunities may have diminished value.

Does this world of expanded educational opportunity magnify inequalities in education by expanding opportunities disproportionately for those already privileged? Or does it reduce inequality by providing more opportunities for persons from disadvantaged families? Or both?

Some argue that expansion of access to higher education is a process of diversion, whereby members of the working class are diverted from elite opportunities and are channeled to positions of lower status. Others, however, argue that even lower-tier postsecondary schooling represents enhanced opportunity, so that the important effect of expansion is more inclusion.

In the book *Stratification in Higher Education: A Comparative Study* (Stanford University Press, 2007), Gamoran and colleagues assess these and other propositions about the relationship between forms of higher education expansion and social stratification. In analyzing and comparing higher education systems in 15 countries, they discuss how class inequalities in access to higher education vary across systems with different levels of expansion, institutional differentiation, and practices of private versus public allocation.

Research teams in the 15 countries analyzed higher educational attainment using nationally representative data. Each team used a framework agreed upon in advance and designed to generate findings that could be compared across countries. The point of the study was to identify systematic inequalities in access to higher education across social strata. (Higher education was defined as postsecondary programs that are either academic or occupationally oriented.)

The study found that expansion of access to higher education can reduce educational inequality, but its effect is not a linear one. Rather, educational expansion tends to reduce inequality when it reaches the point at which educational attainment at a particular level is nearly universal.

Expansion of access to higher education is associated with many advantages, including enhancement of people’s general wellbeing and of societies’ economic development. Higher education serves as a gatekeeper for professional and managerial jobs.

Yet expansion often includes a kind of qualitative differentiation that replaces inequalities in the quantity
of education attained. Some higher education systems consist of a mix of institutions stratified by prestige, resources, and selectivity. The American system, for example, consists of a first tier of prestigious research universities, a second tier of private and public 4-year colleges, and a third tier of 2-year colleges. In diversified systems like that in the U.S., eligibility rates and attendance rates tend to be higher than in binary systems. Binary systems, as found in Britain, France, Germany, and elsewhere, combine academic higher education with second-tier programs that are occupationally oriented. In other words, diversified systems are more inclusive. A larger proportion of the population is eligible for higher education and goes on to attend. Inequality occurs at a lower rate.

As one might expect, private sector funding is associated with inequality in higher education. Gamoran and colleagues found support for the proposition that reliance on private sources of funding is conducive to greater differentiation. In systems with a high degree of private funding, the mode of differentiation is more likely to be diversified than binary.

However, privatization of financial sources of support for higher education can be beneficial to a point. In so far as private funding increases general levels of educational attendance, it reduces inequality of access. Controlling for this expansion, however, one sees that increased reliance on private sources of funding tends to magnify inequality of access. Taken as a whole, privatization is associated with higher education systems and similar aggregate levels of inequality overall.

The study found no significant relation between private funding and attendance in higher education when attendance was considered only for the subset of the cohort that was eligible. This finding suggests that where higher education is largely funded by private sources, it expands through the adoption of lenient eligibility criteria. The findings also suggest that in highly privatized systems class inequalities may reflect family differences in the ability to pay tuition fees.

Policy implications

One report has emphasized that expansion in higher education enables the privileged classes to retain their relative edge in the process of educational stratification (see “Persistent Inequality: Changing Educational Attainment in Thirteen Countries,” by Shavit and Blossfeld, 1993).

Yet Gamoran’s interpretation is different. The expanding pie is increasingly inclusive, even when relative advantages for some are preserved, because it extends a valued good to a broader spectrum of the population. Educational expansion is an equalizing force and diversification is not inconsistent with inclusion.

“When I reported this finding, it was as if I had lit a fuse.”

Over recent decades Peru’s education system has expanded significantly. In spite of that, secondary education is not universal and higher education even less so. There is great inequality with respect to access to education because of divisions among urban and rural populations, and among indigenous and mixed-race groups.

On a recent visit to Peru, Adam Gamoran aroused heated controversy.

He was visiting former graduate students and delivering talks at the Peruvian ministry of education, at a research center, and at the Pontifical Catholic University of Peru.

He spoke on causal effects of social capital, accountability policies in the U.S and their impact on social inequalities, and on the results of privatization in access to higher education. Eyebrows raised as he reported findings that, contrary to conventional wisdom, privatization does not increase inequality in access to higher education.

Because private institutions charge high tuition, students of limited means are less likely to attend. The direct effect of privatization is to increase inequality, as would be expected. However, privatization has countervailing effects that tend to reduce inequality: As the private sector expands, more places are opened for students to enroll in the system as a whole. This tends to reduce inequality. On balance, then, privatization is neutral for inequality.

For more, see Stratification in Higher Education: A Comparative Study. The book details trends in inequality of enrollment in higher education in 15 countries and examines the relation between privatization and inequality.

Photos of Peru courtesy of Adam Gamoran