# Aligning Learning with Life Outcomes through Naturalistic Assessment

## It's Not What You Know, But Why You Learned It

Socos

Socos is creating assessment technologies that seamlessly connect everyday learning activities with life outcomes. We turn naturally-occurring information into actionable feedback for learners and their supporters to guide future action.


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# Executive Summary

Millions of people worldwide miss out on valuable opportunities due to their unrecognized and underdeveloped potential. Yet small interventions at the right time can have large and lasting benefits. At Socos, we believe that education needs to change in its goals, assessment, and instruction to more fully nurture and advance the potential of everyone in our society.

## Problem: Our Educational System Is Too Narrow

*Narrow goals.* Education today promotes and rewards a narrow definition of success: the acquisition of specific content knowledge. This limits the talents developed and favors short-term over long-term success, foregoing later career stability, financial independence, health, and life satisfaction.

*Artificial assessment.* Grades and test scores are biased proxies for future success, are difficult to use, and hinder effective instruction. Tests create artificial, inauthentic environments that do not reflect real-life situations and utilize only a small portion of the relevant data on students' learning. High-stakes tests exaggerate their impact and provide delayed, coarse-grained feedback that aligns poorly with educators' needs. In displacing other instructional activities, testing is very costly, yet yields questionable benefits.

*Short-sighted instruction.* "Teaching to the test" plus demands for "data-driven instruction" magnify the impact of systematic and random biases to produce instruction that conforms to the wrong expectations. Left on their own to solve these problems, teachers and schools are isolated from the environmental context, community, and families.

## Solution: Build Integrated Assessment for Life Outcomes

*Life outcomes.* Our solution is to build assessment technologies aligned with life outcomes, facilitating development of more robust and general *meta-learning*: the knowledge, skills, and dispositions that support learning and applying knowledge productively. These encompass the broad areas of *social skills*, such as leadership, empathy, and collaboration; *self-regulated learning*, such as motivation, resilience, and executive functioning; and *creativity*, such as exploration, innovation, and divergent thinking. Linked with improved long-term health, educational, and employment outcomes, these habits are mechanisms for future growth and can be learned.

*Naturalistic data.* We draw from a continuous stream of the data naturally embedded within everyday experiences and the existing activities that instructors choose. These may include parent-child conversations; student-produced artifacts; digital and audio capture of student-faculty interactions; online collaborations; *etc.*

*Continuous predictive assessment.* Our algorithms provide *formative assessment* linking dynamic, automated predictions with actionable feedback. Such information connects future possibilities with current realities via concrete recommendations for immediate actions, as well as longer-term perspective shifts and course corrections.

*Resilient, responsive instruction.* Successful pathways need to accommodate difficulties and failures safely; the experiences that develop capacities for long-term success may not always appear to produce short-term success. By facilitating and creating new norms around iteratively examining, inferring, and influencing student thinking, we are establishing a culture of ongoing assessment which respects these constraints and constructively informs practice.

*Integrated systems.* Our technologies integrate seamlessly with the roles that teachers, students, parents, and colleagues already assume in everyday experiences in their natural learning ecosystems. Personalized feedback empowers learners and educators with the freedom to draw from their own expert judgments, rather than forcing them into preset paths.

Socos designs machine intelligence to augment human intelligence by synergizing actions across all of these aspects of the learning process.

# Introduction: Defining the Problem

Millions of adults and children in the U.S. and around the world miss out on valuable opportunities due to their unrecognized and undeveloped potential, at tremendous cost to society. That ZIP codes continue to serve as a reliable predictor of test scores exposes the myth of equal access to educational opportunity. The lost human capital associated with the U.S. achievement gap has been estimated at over $1.3 trillion GDP in 2008,[1] with future projections of $2.3 trillion from 2014 to 2050.[2]

Surprisingly small, low-cost interventions at the right time can have large and lasting impacts on health, psychological well-being, educational attainment, and economic output. Early childhood interventions can bring particularly significant impacts down the road.[3] They may be as brief as seven weeks of training mothers in nurturant parenting skills, which yielded better health outcomes for their children upon reaching adulthood eight years later.[4] Longer and earlier interventions can erase equity gaps. A random sample of families of severely underprivileged toddlers received two years of weekly visits focused on parenting that promotes cognitive and socioemotional skills. Twenty years later, those toddlers had grown up into adults with 25% higher earnings, now matching those of peers with no such early-childhood disadvantages.[5]

These profound results are inspiring, showcasing what can be done, while also underscoring the question: How can our education system serve us all better? At Socos, we believe that education needs to change on all three dimensions—goals, assessment, and instruction—to more fully nurture and advance the potential of everyone in our society. These changes require greater equity in developing skills across the population, more active engagement by students in their education, and better coordination with the affordances of the learning ecosystem. All of these translate into better resource utilization and greater returns on investment.

> Unequal access to opportunity accumulates costly equity gaps in health, well-being, education, and earnings later in life.

## Traditional Educational Goals Are Too Narrow

The present educational system promotes and rewards a narrow definition of success: the acquisition of specific content knowledge within only certain domains. Failing to recognize and nurture other forms of success constrains the range of talents and skills that are developed. This limited focus also favors short-term achievement over long-term success and becomes especially problematic upon recognizing that their paths diverge. Mastering a particular domain offers no guarantee of career stability, financial independence, health, or life satisfaction, and pursuit of short-term success may even come at the expense of these life outcomes.[6,7] As valuable as specific expertise is, it fails to transfer to the new knowledge domains emerging ever more rapidly in today's information age. Increased attention to the importance of other factors such as socioemotional competency, mindsets, motivation, grit, and conscientiousness has highlighted the need for educational goals to encompass these habits of mind alongside domain-specific knowledge and skills.

> Mastering a particular domain offers no guarantee of career stability, financial independence, health, or life satisfaction.

## Test-Based Assessment Exaggerates Artificial Experiences

Effective instruction depends on *formative assessment* to discover and monitor student understanding,[8] yet the design and use of today's tests carry many problems. Tests are valid only for the population and purpose for which they were designed; eliminating cultural bias from tests is extremely difficult,[9] and tests are often designed as sequestered experiences stripped from authentic contexts. Standardization narrows the range for what is considered acceptable progress regardless of developmental variation, and testing is intrusive, displacing instruction which might yield better learning. Assessment needs to resolve these dilemmas to be truly useful.[10]

### Grades Provide Biased and Incomplete Information

Grades and test scores are imperfect proxies for later success. While SATs are predictive of first-year college grade point average,[11] they do not predict subsequent career performance; demographic and socioeconomic variables are more predictive.[12] Internal research at Google has also shown that GPA and brainteaser performance did not predict job success.[13] These markers are both misleading and biased. Given the diversity in students' interests and experiences, the multiple specializations demanded by our society, and the rapidly-changing needs of the labor market, grading performance by a narrow set of standards simply cannot capture the depth and breadth of important information with the speed and accuracy we seek.

### Inauthentic Assessments Use Misleading Input

Artificial assessment events produce *non-naturalistic data* and interrupt rather than inform instruction.

The flaws of today's high-stakes, standardized assessment system go beyond their goals. Not only are they aligned to the wrong outputs, but they also focus on the wrong inputs and are difficult to use. While they stipulate narrow controls over testing environments and proctoring, inconsistencies and irregularities in test administration challenge assumptions of identically and comparability. Such tests use a very small portion of the available and relevant data on students' learning and are derived from *non-naturalistic data* based on artificial assessment events. They bias action based on incomplete information and exaggerate the impact of those limited snapshots, due to their high-stakes application. In seeking to assess everyone by standardized measures, they neglect information that could distinguish among the unique experiences, strengths, and paths by which they meet different roles and needs.[14] Attempting to sanitize tests of the contaminating effects of context produces inauthentic "sequestered problem-solving" that no longer reflects real learning experiences.[15] Given these rigid controls, test administration becomes an intrusive process that disrupts and displaces normal instruction. While well-designed tests can facilitate learning,[16] the best testing activity may not be the best learning activity at a particular moment.

### Conventional Assessment Offers Limited Feedback

Today's assessments are poorly equipped to provide useful information to the many stakeholders who rely on them for guidance. Designed as summative rather than formative measures, standardized tests typically provide only delayed, coarse-grained feedback that may be difficult to understand and align with teachers' and administrators' experiences and needs. Having been developed according to a carefully designed framework and format to ensure comparability against standards and between students, these tests mandate organizing the intake and output of information according to rigid specifications. On the opposite end, teacher-developed formative assessment is easier to interpret and integrate into instructional practice, due to being more tightly connected to classroom learning. Yet both focus on narrow expectations of knowledge, resulting in a very short cycle of relevance. Neither accounts for learners' needs for direct, individualized feedback on how to adapt their efforts effectively toward their long-term goals.

## Short-sighted Instruction Targets the Wrong Goals from the Wrong Data

Teaching toward ambitious goals requires new processes, not just new standards. Simply declaring perseverance or pro-social behavior as goals does not develop those habits; they are not mere traits to request and reward, but rather skills to scaffold carefully. Many tout the classic "marshmallow experiment"[17] to highlight how children's ability to defer gratification predicts later success: those who were able to resist the first marshmallow for 15 minutes to earn a second marshmallow showed higher test scores, greater educational attainment, and better health in adulthood.[18,19,20] Yet in a follow-up study, children who were promised but then denied replacements for their broken crayons learned that the rational choice was to eat the first marshmallow right away.[21] Living in an unpredictable environment where critical resources are often absent interferes with the desired lessons. We do not impart growth mindsets or self-efficacy by mere lecture, nor can we teach creative problem-solving and adaptive expertise through incremental problems and familiar routines with known answers.

> Too often, today's appetite for "data-driven instruction" inflates the power of limited data in influencing that instruction.

The dominant relationship between instruction and assessment is problematic. Today's appetite for "data-driven instruction" too often inflates the power of the limited data beyond the inferences they support, hiding the uncertainties and rushing to judgment amidst eagerness for action. Relying on a narrow slice of data, overcorrecting in response, and using data for high-stakes evaluation are miscalculations which oversell and ultimately undermine trust in data. How we use assessment needs to change in both timescale and purpose. As the assessment intervals become narrower, the outcomes considered should become broader. Hewing too closely to local fluctuations can miss more important global trends, and short-term gains do not always translate into robust long-term retention and transfer.[22] Snapshots are not trajectories, and averages are not individuals. Information should be used to improve guidance and support, not as evaluative judgment. Granting too much power to a momentary glimpse risks magnifying the impact of both systematic and random biases, closing windows of opportunity where they should be opened. It is a mistake to presume that the fault lies with the individual rather than the system.

Where that system needs repair is in its fragmentation and failure to engage and coordinate all its members productively toward shared goals. For example, the stress of living in an unreliable environment impairs working memory, which is fundamental for language learning, problem-solving, and long-term memory.[23] Those deficits then impede parenting effectiveness,[24] which creates a self-perpetuating cycle. We cannot expect teachers and schools to solve these problems single-handedly, when in reality the environmental context, community, and families all play major roles and likewise need support.

## The Socos Solution

To solve these problems, Socos is implementing technologies that align assessment with life outcomes as goals, drawing continuously from naturalistic data to create dynamic, formative predictions connecting actions to outcomes. These technologies integrate seamlessly with the roles that teachers, students, parents, and colleagues already assume in everyday learning environments.

### Focus on Life Outcomes

What matters more than a particular body of knowledge is the ability to learn whatever knowledge is needed and to deploy that knowledge productively. We define this construct of *meta-learning* as the knowledge, skills, and dispositions that support learning and applying knowledge effectively. Meta-learning encompasses abilities and habits as diverse as metacognition, self-efficacy, socioemotional competency, creativity, and curiosity, variously labeled as "soft skills," "deeper learning," "non-cognitive factors," "21st century skills," "skills for success," among other terms.[25,26,27] Recognizing that the research literature is itself somewhat fluid regarding their categorization, we offer the following illustration as just one representation of how these constructs may be seen as clustering together (*Figure 1*).

> Long-term success depends on *meta-learning*: the knowledge, skills, and dispositions that support learning and applying knowledge.

Evidence for the value of these skills continues to grow, linking mental well-being and socioemotional instruction to improved health and employment outcomes, even showing stronger effects than for academic achievement.[28,29,30,31] Adopting a *growth mindset*, or the belief that intelligence and social attributes can be developed, fosters resilience.[32,33] In contrast, incentivizing performance over learning can undermine internal motivation and long-term persistence.[34,35] Childhood levels of conscientiousness, self-control, the ability to delay gratification, and emotion regulation predict health, educational and employment success, income, and marital stability in adulthood.[36,37,38,39,40] Yet grit, consistency, and perseverance do not predict creative success; openness to new experiences does.[41,42] Creative exploration itself facilitates novel discoveries, solutions, and inventions, as well as new pathways for learning and the development of self-regulation.[43,44]

What sets these skills and dispositions apart from traditional academic achievement is that they serve as mechanisms for learning and applying new knowledge. They represent potential for future growth, not merely evidence of past development which may not transfer to new contexts. Too often, underprivileged learners are relegated to a narrow and disengaging curriculum that overlooks complex skills which enable and promote future learning.[45] Simply assuming that these skills will develop on their own is not sufficient; education needs to target them deliberately, and for all learners.

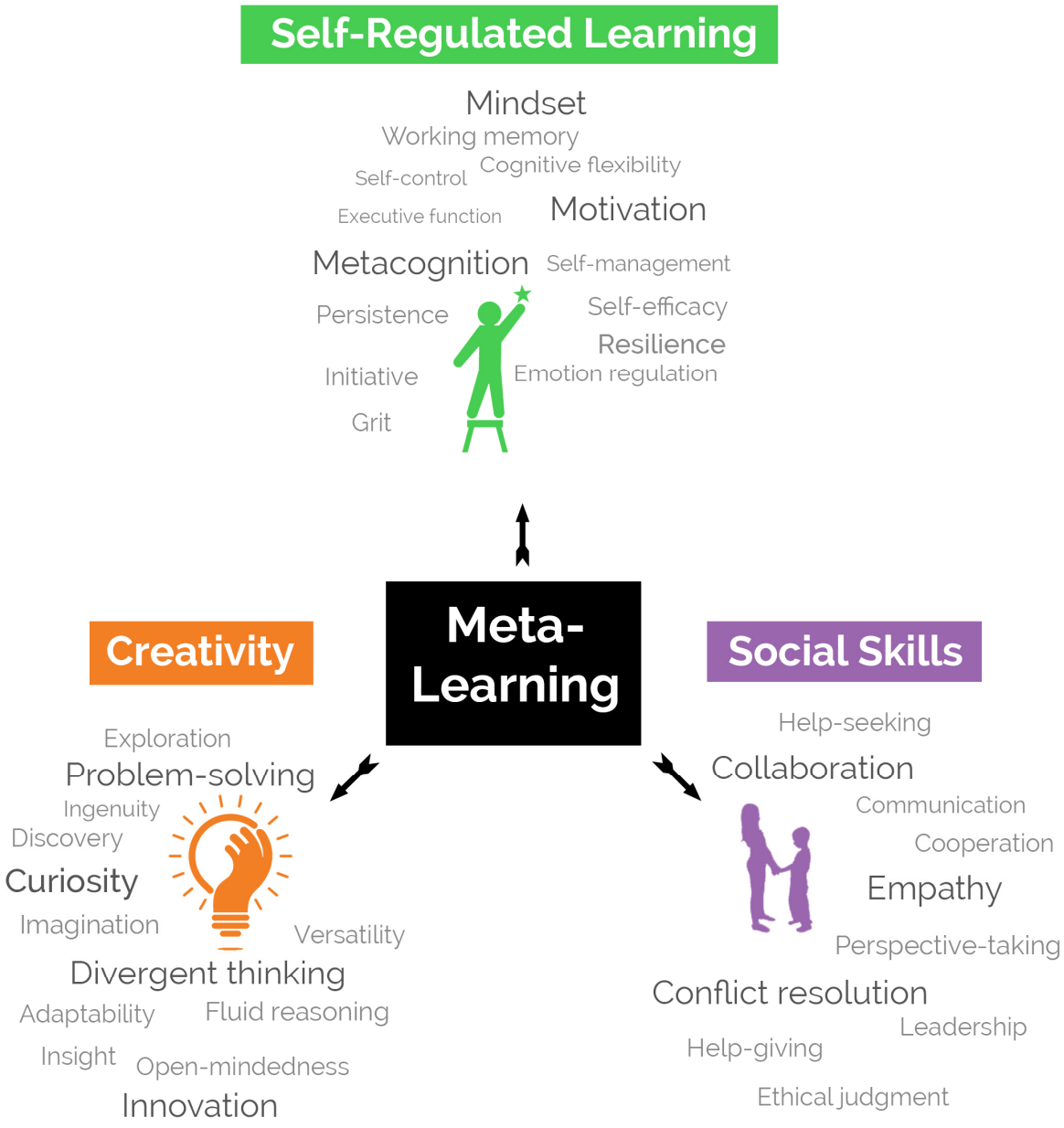


*Figure 1. Meta-learning comprises multiple dimensions and components*

## Use Naturalistic Data for Continuous Predictive Assessment

### Align Outputs with Life Outcomes

Changing the goals of education necessitates changing the assessment to align with those goals. Rather than measuring short-term knowledge, we are designing assessments that measure progress toward meta-learning goals and long-term life outcomes to provide useful information for guiding immediate actions.

Building assessment upon the *naturalistic data* already embedded in existing activities enables teachers and learners to pursue the most valuable learning experiences for their needs.

### Use Naturalistic Data as Inputs

These measurements derive from data already available on a broad range of learning experiences. Instead of halting instruction to collect data on students, whether through a test, survey, or other manufactured experience, teachers should be free to choose the activities that best meet their students' needs. Assessment information would then flow from the *naturalistic data* already embedded within those activities, as shown in *Figure 2*. Defining what students need to know and be able to do should still motivate the instructional design,[46] but monitoring and developing student knowledge should function in tandem, not in opposition.

To maximize their utility in assessing meta-learning goals, our algorithms incorporate a wide range of data collected continuously across diverse experiences. These may include student-produced writing, drawing, and equations; in-class audio recordings; digital and audio capture of student-faculty interactions; faculty feedback; tutor logs; micro-world and simulation choices; and online discussion forums, wikis, and blogs. Individually and contextually tailored prompts may further elucidate knowledge, attitudes, and behaviors. By utilizing data collected unobtrusively, without interfering with instruction, this system grants teachers and learners the freedom to pursue the most valuable learning experiences.

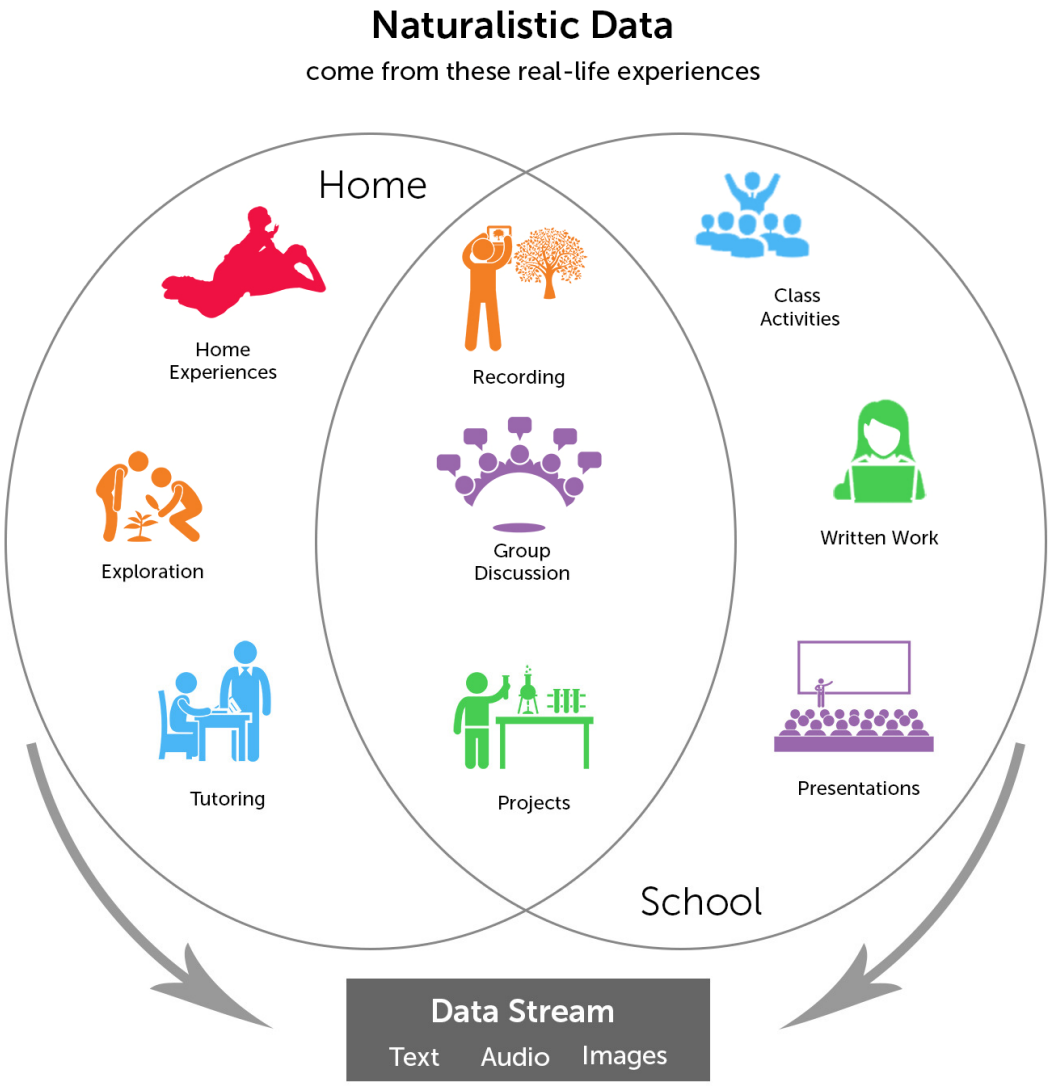


*Figure 2. Naturalistic data flow from everyday life experiences such as these.*

## Automate Predictions and Connect Them to Recommended Actions

Making assessment useful and actionable requires bridging goals and instruction for all stakeholders. Assessment connects the minutiae of everyday instruction with long-term goals, going beyond merely documenting the recent past to generating predictions about how to influence the future. These predictions integrate across the wealth of information from past history and update dynamically as the learning status changes, to anticipate the likely future outcomes of a range of possible actions.

We translate assessment information into effective action by all the players in the ecosystem.

As powerful as it is, manual analysis by a team of experts demands patience and resources, and does not scale to rapidly-shifting knowledge domains and student populations. Our algorithms provide real-time, automated, and personalized formative assessment information to teachers and learners that they can act on immediately when it matters. Rather than trusting the data to speak for themselves, we

translate assessment information into effective action by all the players in the ecosystem, through opportunities appropriate for their roles. The outputs of these analyses merge invisibly with existing tools and communities, to make the information easy to use effectively within their natural ecosystems. In concert with teacher dashboards, online profiles, and student portfolios, our system provides concrete recommendations for immediate actions as well as longer-term perspective shifts and course corrections. While predictions are linked to possible actions, the information complements teachers' expertise, empowering them with freedom and flexibility to draw from their own professional judgment about their best options, rather than forcing them or their students into preset paths. Recommendations to students, parents, caregivers, colleagues, and supervisors likewise adapt to their particular roles and strengths, offering timely feedback that is easy to convert into action. We design machine intelligence to augment human intelligence by working together collaboratively.

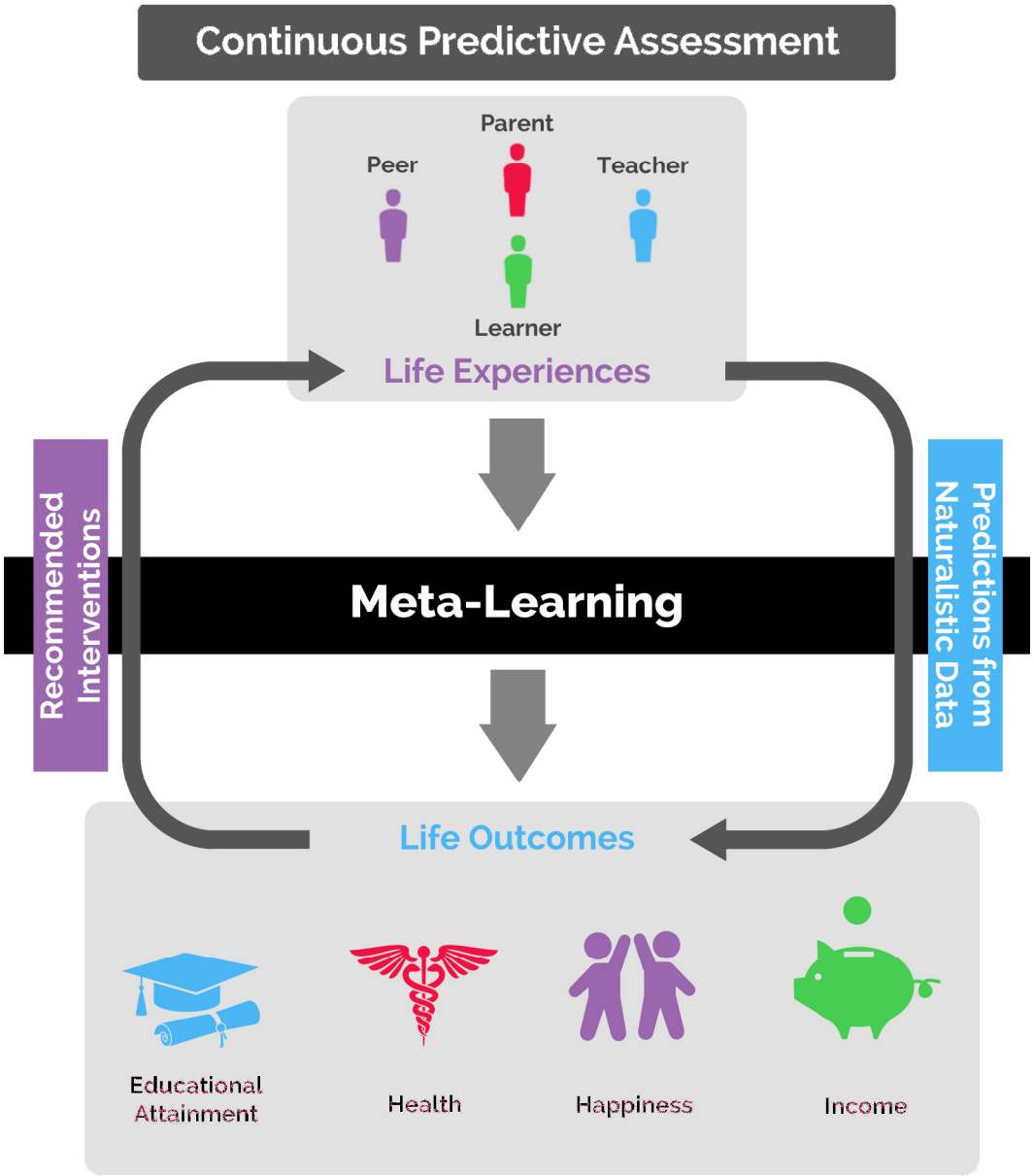


*Figure 3. Continuous predictive assessment connects tomorrow's potential to today's actions.*

## Facilitate Instruction of Desirable Goals Using Effective Assessment

Substantive instructional revisions must accompany these changes in both goals and assessment. Most obviously, different goals require different instruction. Learning to defer gratification demands reliably experiencing the benefits of deferred gratification. Likewise with learning that errors are constructive, that hard work will pay off, or that conflicts can be resolved, successful pathways need to accommodate difficulties and failures safely. This entails granting students more control over their learning, encouraging open-ended exploration and discovery, and allowing room to make and recover from mistakes, without fear of wrong moves getting documented and docked. Given greater autonomy and a more personally meaningful curriculum, students become more deeply engaged and invested in their learning.

Education that targets distant objectives must allow for successful pathways that accommodate difficulties and failures safely.

Since teachers' instructional practices are tightly intertwined with the assessment system, establishing a culture in which formative assessment informs practice constructively is essential. The experiences that develop capacities for success in the long term may not always appear to produce success in the short term from a superficial glance, a key distinction to highlight when presenting information. Call it productive struggle, teachable moments, U-shaped development, or lifelong learning; education that targets distant objectives must itself model a growth mindset and take a long view of assessment data, premised upon the potential for change. Hence, we are building a technology to change instruction so that it is fundamentally interwoven with ongoing formative assessment framed in this context. By giving teachers a continuous stream of actionable information linked with past and future outcomes, we facilitate the process of examining, inferring, and influencing student thinking in connection with distant goals, thereby also creating new, achievable norms around it. Rapid analysis and iteration upon student data likewise become not just an option but an expectation. This shifts the assessment culture away from fearing tests as evaluation, toward seeking and trusting data for guidance. Armed with greater self-knowledge, students are able to take more active responsibility in directing their learning, ultimately becoming their own best teachers.

Recognizing that learning is embedded within a broader ecosystem, we are designing tools that incorporate the resources and roles played by other partners in that system. This includes not just students, teachers, and administrators, but also parents, caregivers, peers, and others. For students, interventions target attitudes and strategies for approaching the learning process. Some successful examples reduce stress, promote growth mindset, and increase feelings of self-efficacy and belonging.[47,48] For teachers, tutors, and mentors, interventions provide assistance with how, when, and to whom to offer scaffolding and feedback.

Key recommendations may include reaching out to students at risk of dropout or failure,[49] highlighting missing skills and concepts to target,[50] or modeling skills to be learned rather than only teaching them explicitly.[51,52] Teachers can promote metacognitive abilities by engaging students in discussions on general reflection prompts that focus on the question rather than the answer, or by facilitating small group discussions among peers of different ability levels and backgrounds that require them to bridge these differences.[53,54] Actions for administrators include developing models for connecting student data to instructional practice, designing respectful and collaborative environments for examining data, and creating a supportive climate for integrating the use of data in key decision-making junctures.[55] As noted in the introduction, parents benefit from timely training in specific skills;[4,5] targeted feedback based on actual needs can further improve caregiving practices by focusing their efforts more efficiently. Productive peer involvement may be scaffolded through selecting complementary group participants, creating collaboration scripts, or prompting them with discourse strategies for effective idea exchange.[56,57,58]

These techniques can greatly impact students' long-term development when used at the right time and embedded in the right context. We have learned from successful holistic interventions, such as socioemotional learning or resilience programs,[59,60] that for such approaches to work effectively, we need to orchestrate the actions on the teacher, school, parent, community, and student levels.

# Case Studies

## Assessing and Facilitating Online Discussions

In a large-scale validation of Socos's pioneering approach to unstructured assessment, we demonstrated our ability to detect and visualize key features of student learning that predict end-of-course grades.[61] Our algorithms analyzed the relationships in the topics within student-generated text in online class discussions for 1200 students at a large university. We extracted patterns which successfully predicted final grades within half a letter grade from just two weeks of discussions, which constituted between 4 and 8% of the work composing their total grade. Incorporating a greater quantity and range of student writing would improve those predictions and enrich the possible inferences. Our analyses also yielded preliminary topic maps to trace different trajectories in student thinking. Adding instructors' comments, assigned reading from the textbook, or other course materials would further elucidate distinctions between normative and non-normative concepts on those topic maps.

In related research examining student-faculty interaction patterns in online discussions at the same university, we combined text mining with close reading to uncover facilitation strategies associated with discussion quality.[62] Visualizations of topical and temporal development in six case studies revealed suggestive patterns between facilitation styles, discussion focus, and evidence of learning. Such information could help both students and instructors monitor and adapt the content of their discussion participation to enable better learning.

We successfully predicted final grades from just 4-8% of the work composing total grade.

These unstructured assessment techniques can be readily applied to other forms of open-ended text beyond online discussions, such as essay questions, tutoring and email exchanges, wiki contributions, and annotations on electronic texts. Discovering and depicting emergent interaction patterns based on semantic and syntactic content can reveal nuances in the relationships between ideas as well as people, highlighting features that might otherwise have required multiple re-readings or aggregating across thousands of instances. Automated feedback to students could signal if their response to a question has omitted a key concept or evidences a common misconception, suggesting relevant resources to review for their revision. It could identify which parts of their discussion contribution reflect ideas shared with many classmates and which parts present an unusual thought. Faculty alerts can prompt them to intervene early in counterproductive discussions, to redirect ineffectual exploration, to guide a student on the brink of giving up, or to assemble discussion groups to explore different perspectives rather than merely reinforce shared beliefs. These examples illustrate just a few paths by which unstructured assessment informs and empowers learners and instructors.

## Supporting Competency-Based Learning

To move beyond conventional tests and grades, Socos is partnering with a competency-based online college to develop new methods of direct assessment of real-life learning experiences. Rather than earning credits for seat time and percentage scores based on arbitrary start and end points, students tackle competencies suited to their needs and pacing. Reviewers offer feedback and coaches offer guidance on students' work to help them revisit and refine their efforts until they achieve mastery.

> Our technology provides a continuous stream of actionable information to build self-directed learning and other competencies.

In this paradigm, rather than validating our assessment algorithms against grades, we are validating them as aligned to life outcomes to certify competencies. Learning goals address self-directed learning, critical thinking, and collaboration, and success is measured in terms of persistence and progression toward those goals. This requires mapping features of unstructured student work to established program goals and competencies. Linking this competency map to in-demand job skills can further help gauge progress in students' career trajectories, holding the school accountable to the practical realities of employers' needs, not just the theoretical aspirations of other educational institutions and their accreditors.

For this project we are building upon our previous work by incorporating multiple data sources, such as comprehensive student profiles, coach calls and email exchanges, reviewer feedback, peer interactions, and of course original student work. Our analyses will provide predictions about individual students' future performance, as well as constructive feedback to coaches and reviewers via an adaptive guide for leveraging student strengths to better help them improve in school and life outcomes. Information may include warnings about disengagement, recommendations of known interventions, or guidance around what to prioritize or how to frame suggestions for students. By offering more timely and specific feedback through these automated analyses, this system can effectively guide self-assessments, instructional coaching, peer learning arrangements, and employer mentoring. This enables students to take greater initiative in directing their own learning successfully, while also facilitating better involvement by partners in multiple roles.

## Kindersight: Engaging Parents and Teachers of Early Learners

Working with researchers at a major university, Socos is building an innovative method for assessing young children's linguistic and metacognitive development in richer detail and more naturalistic contexts. The new system extends our existing assessment algorithm for adult learners to deliver rapid, actionable feedback for parents, teachers, and caregivers based on the broad range of learning experiences already taking place in the classroom and at home. Many current initiatives demonstrate the effectiveness of educating parents in the importance of talking to young children for improving long-term language development and reducing the word gap.[63,64] Texting parents of preschoolers with just-in-time suggestions for home literacy activities boosted early literacy skill as well as parental involvement in school.[65]

Analysis of young children's linguistic experiences from audio recordings has demonstrated the feasibility of automatically tracking word exposure and adult-child conversational turns. We are deploying similar technology throughout kindergarteners' learning environment in conjunction with location data and analyzing them with our continuous passive assessment algorithms. By producing a map of young learners' conceptual space, we can explore the predictive value of the language they generate and hear from peers and adults in each language. Combined with student artifacts and information about classroom activities, these data sources together illuminate students' knowledge and skills, which we then connect with externally validated assessment outcomes. This system thus elucidates school and home interventions with the greatest potential to boost learning.

> By mapping children's language experiences and knowledge, we help their caregivers support learning.

Amidst a growing movement to increase standardized testing despite questionable developmental appropriateness, our system alleviates those pressures by capturing information from whichever learning experiences teachers choose for maximal instructional value. Merging information across school and home environments promotes collaboration between teachers and caregivers, enabling complementary rather than redundant efforts. It could clarify the relative effectiveness of parental contributions in reinforcing school lessons (repeating the same language), elaborating upon them (adding new language), or posing questions about them (inviting the generation of language). It further legitimizes informal and less-structured learning activities that may not traditionally be considered "educational," changing the norm from teacher-centered transmission not just to adult-facilitated elicitation but even to child-directed exploration.

Beyond simply enriching children's vocabularies, supporting their linguistic development in real-world contexts directly advances their skill by using language for its metacognitive, pragmatic, and social functions. These are all fundamental tools for monitoring, guiding, self-regulating, and enhancing one's own learning and actions. Our system augments the critical support of caregivers through brief messages informing and guiding their interactions with the children. Our ultimate goal is not only to provide daily, personalized interventions to decrease the word gap, but to drive the development of broader lifelong meta-learning skills.

# About Socos

Everyone at Socos has a very personal relationship with educational technology, research, and teaching. Co-founder Vivienne Ming, Ph.D., named one of 10 Women to Watch in Tech in 2013 by *Inc. Magazine*, is a theoretical neuroscientist, technologist and entrepreneur.

Vivienne is a visiting scholar at UC Berkeley's Redwood Center for Theoretical Neuroscience. She sits on the boards of StartOut, Emozia, and Our Family Coalition and speaks on issues of LGBT inclusion and gender in technology. Previously, she was a junior fellow at Stanford's Mind, Brain & Computation Center and earned her Ph.D. from Carnegie Mellon. Her work and research has received extensive media attention including the *New York Times*, *NPR*, *Nature*, *O Magazine*, *Forbes*, and *The Atlantic*.

Vivienne's career led her to work at Gild as Chief Scientist, where she applied computational neuroscience to create algorithms to finding within a database of ten million software developers, the diamonds-in-the-rough, individuals with the prerequisite talent who had been overlooked. She left her role at Gild to devote all of her attention to Socos, and brings with her the computational knowledge gleaned while working with millions of professionals to Socos's mission of maximizing human potential.

Vivienne co-founded Socos with her wife, Norma Ming, PhD, a learning scientist and educational technology thought leader who works at the intersection of research, development, policy, and practice. Norma is a Supervisor of Research at the San Francisco Unified School District, where she develops and produces results-oriented research to inform the district's implementation of its strategic plan. A former high school educator, she published original research and policy papers as a Senior Research Scientist at the Nexus Research and Policy Center and taught as a lecturer at UC Berkeley's Graduate School of Education. She earned an A.B. with honors in chemistry at Harvard University and a Ph.D. in cognitive psychology in the Program for Interdisciplinary Educational Research at Carnegie Mellon University.

Norma merges a pragmatic understanding of the teaching enterprise with a long-term, system-wide vision of how research can illuminate and policy can facilitate more effective learning. Her experience in teaching, professional development, assessment design, and curriculum evaluation crosses multiple disciplines and spans elementary through postgraduate students, teachers, administrators, and faculty trainers. Research projects have explored relationships among predictors, processes, and outcomes across a range of student populations and instructional models, from case studies to massive scale, individual or collaborative, with and without technology. Her policy advocacy highlights issues of equity in creating flexible paths and innovative resources to enable all learners to meet high expectations.

The Mings are joined by Engin Bumbacher, also a theoretical neuroscientist and Director of Research at Socos. Engin is devoted to the development of the company's core cognitive modeling and predictive analytics technology. He is presently pursuing his Ph.D. in Education at Stanford, where he explores alternative approaches to STEM education that leverage novel technologies, teaching, and learning practices. This work is partly motivated by the question of why people do or do not identify as a 'science person', and how such self-limitations can be overcome. To this end, Engin is using machine learning to understand students' cognitive and learning processes based on unstructured data. Additionally, he is designing frameworks for technologies that foster the students' self-efficacy and learning process in project-based learning environments.

Engin completed his master's thesis project at the Redwood Center for Theoretical Neuroscience at UC Berkeley under the supervision of Dr. Vivienne Ming, applying and further developing elaborate models of information processing to human speech and music. Engin earned his master's degree with honors in Neural Systems and Computation from the Swiss Federal Institute of Technology Zurich and the Institute of Neuroinformatics, both researching in the field of theoretical neuroscience and exploring models of collective intelligence through implementation of interactive flocking algorithms to control computer sound synthesis and 3D sound positioning. Prior to that, he finished his B.S. with honors in Physics at the same university.

## Concluding Remarks

The Socos team is the only group currently taking naturalistic student experiences as the basis for assessments. The solution to improving education and the learning gap is to close the educational loop, and provide relevant feedback to educators and parents on what they can do in naturalistic setting to improve life-outcomes. Socos is in the position to make this possible.

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## REFERENCES


[1] McKinsey & Company. (2009). *The Economic Impact of the Achievement Gap in America's Schools.*

[2] Lynch, R.G., & Oakford, P. (2014). *The economic benefits of closing educational achievement gaps: Promoting growth and strengthening the nation by improving the educational outcomes of children of color.* Washington DC: Center for American Progress.

[3] Karoly, L. A., Kilburn, M. R., & Cannon, J. S. (2006). *Early childhood interventions: Proven results, future promise* (Vol. 341). Santa Monica CA: Rand Corporation.

[4] Miller, G.E., Brody, G.H., Yu, T., & Chen, E, (2014). A family-oriented psychosocial intervention reduces inflammation in low-SES African American youth. *Proceedings of the National Academy of Sciences, 111*(31), 11287-11292.

[5] Gertler, P., Heckman, J., Pinto, R., Zanolini, A., Vermersch, C., Walker, S., Chang, S.M., & Grantham-McGregor, S. (2014). Labor market returns to an early childhood stimulation intervention in Jamaica, *Science, 344* (6187), 998-1001.

[6] Blanden, J., Gregg, P., & Macmillan, L. (2007). Accounting for Intergenerational Income Persistence: Noncognitive Skills, Ability and Education. *The Economic Journal*, *117*(519), C43-C60.

[7] Carneiro, P., Crawford, C., & Goodman, A. (2007). *The Impact of Early Cognitive and Non-Cognitive Skills on Later Outcomes* (CEE DP 92). London: Centre for the Economics of Education.

[8] Pellegrino, J.W., Chudowsky, N., & Glaser, R. (2001). *Knowing What Students Know: The Science and Design of Educational Assessment*. Washington, DC: National Academy Press.

[9] Helms, J. E. (1992). Why is there no study of cultural equivalence in standardized cognitive ability testing?. *American Psychologist*, *47*(9), 1083.

[10] Schwartz, D., Lindgren, R., Lewis, S. (2009). Constructivism in an age of non-constructivist assessments. In *Constructivist Instruction: Success or Failure?* (pp. 34-61). New York, NY, US: Routledge/Taylor & Francis Group.

[11] Geiser, S., & Studley, W. R. (2002). UC and the SAT: Predictive validity and differential impact of the SAT I and SAT II at the University of California. *Educational Assessment, 8*(1), 1-26.

[12] Rothstein, J. M. (2004). College performance predictions and the SAT. *Journal of Econometrics, 121*(1), 297-317.

[13] Bryant, A. (2013 June 19). In head-hunting, big data may not be such a big deal. *New York Times*, p. F6.

[14] Ming, N.C. (2013). *Standardization and personalization in education: What should stay constant, and what should vary?* Working paper #2013-01.

[15] Bransford, J.D. & Schwartz, D. (1999). Rethinking transfer: A simple proposal with multiple implications. R*eview of Research in Education, 24*, 61-100.

[16] Wiliam, D. (2011). What is assessment for learning?. *Studies in Educational Evaluation, 37*(1), 3-14.

[17] Mischel, W., & Ebbesen, E.B. (1970). Attention in delay of gratification. *Journal of Personality and Social Psychology, 16*(2), 329–337. doi:10.1037/h0029815

[18] Mischel, W., Shoda, Y., & Rodriguez, M.I. (1989). Delay of gratification in children. *Science 244*, 933–938. doi:10.1126/science.2658056

[19] Ayduk, O.N., Mendoa-Denton, R., Mischel, W., Downey, G., Peake, P.K., & Rodriguez, M.I. (2000). Regulating the interpersonal self: Strategic self-regulation for coping with rejection sensitivity. *Journal of Personality and Social Psychology 79* (5): 776–792. doi:10.1037/0022-3514.79.5.776

[20] Shoda, Y., Mischel, W., & Peake, P.K. (1990). Predicting adolescent cognitive and self-regulatory competencies from preschool delay of gratification: Identifying diagnostic conditions. *Developmental Psychology 26* (6): 978–986. doi:10.1037/0012-1649.26.6.978

[21] Kidd, C., Palmeri, H., & Aslin, R. N. (2013). Rational snacking: Young children's decision-making on the marshmallow task is moderated by beliefs about environmental reliability. *Cognition, 126*(1), 109-114.

[22] Schmidt, R.A., & Bjork, R.A. (1992). New conceptualizations of practice: Common principles in three paradigms suggest new concepts for training. *Psychological Science, 3*(4), 207-217.

[23] Evans, G.W., & Schamberg, M.A. (2009). Childhood poverty, chronic stress, and adult working memory. *Proceedings of the National Academy of Sciences, 106*(16), 6545– 6549.

[24] Deater-Deckard, K., Sewell, M.D., Petrill, S.A., & Thompson, L.A. (2010). Maternal working memory and reactive negativity in parenting. *Psychological Science, 21*(1), 75-79.

[25] Pellegrino, J. W., & Hilton, M. L. (Eds.). (2013). *Education for life and work: Developing transferable knowledge and skills in the 21st century*. Washington DC: National Academies Press.
[26] Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., & Rumble, M. (2012). Defining twenty-first century skills. In *Assessment and Teaching of 21st Century Skills* (pp. 17-66). Netherlands: Springer.
[27] Tooley, M., & Bornfreund, L. (2014). *Skills for Success: Supporting and Assessing Key Habits, Mindsets, and Skills in PreK-12*. Washington DC: New America Foundation.
[28] Durlak, J. A., Weissberg, R. P., Dymicki, A. B., Taylor, R. D., & Schellinger, K. B. (2011). The impact of enhancing students' social and emotional learning: A meta-analysis of school-based universal interventions. *Child Development, 82*(1), 405–432.
[29] Johnston, D.W., Schurer, S., & Shields, M.A. (2013). Exploring the intergenerational persistence of mental health: Evidence from three generations. *Journal of Health Economics, 32*(6), 1077-1089. doi:10.1016/j.jhealeco.2013.09.001
[30] Roberts, B. W., Kuncel, N. R., Shiner, R., Caspi, A., & Goldberg, L. R. (2007). The power of personality: The comparative validity of personality traits, socioeconomic status, and cognitive ability for predicting important life outcomes. *Perspectives on Psychological Science, 2*(4), 313-345.
[31] Sacker, A., & Cable, N. (2006). Do adolescent leisure-time physical activities foster health and well-being in adulthood? Evidence from two British birth cohorts. *The European Journal of Public Health*, *16*(3), 331-335.
[32] Dweck, C. (2006). *Mindset: The New Psychology of Success*. New York: Random House.
[33] Yeager, D.S., & Dweck, C. (2012). Mindsets that promote resilience: When students believe that personal characteristics can be developed. *Educational Psychologist, 47*(4), 302-314.
[34] Grant, A. M. (2008). Does intrinsic motivation fuel the prosocial fire? Motivational synergy in predicting persistence, performance, and productivity. *Journal of Applied Psychology, 93*(1), 48.
[35] Wrzesniewski, A. , Schwartz, B. , Cong, X. , Kane, M. , Omar, A. , & Kolditz, T. (2014). Multiple types of motives don't multiply the motivation of West Point cadets, *Proceedings of National Academy of Sciences, 111*(30), 10990-10995.
[36] Mischel, W., & Ebbesen, E.B. (1970). Attention in delay of gratification. *Journal of Personality and Social Psychology, 16*, 329–337.
[37] Eisenberg, N., Duckworth, A.L., Spinrad, T.L., & Valiente, C. (2014). Conscientiousness: Origins in childhood? *Developmental Psychology, 50*(5), 1331–1349.
[38] Roberts, B. W., Lejuez, C., Krueger, R. F., Richards, J. M., & Hill, P. L. (2012). What is conscientiousness and how can it be assessed? *Developmental Psychology, 50*, 1315–1330
[39] Moffitt, T. E., Arseneault, L., Belsky, D., Dickson, N., Hancox, R. J., Harrington, H., & Caspi, A. (2011). A gradient of childhood self-control predicts health, wealth, and public safety. *Proceedings of the National Academy of Sciences, 108*, 2693–2698
[40] Blair, C., & Raver, C.C. (2014). Closing the achievement gap through modification of neurocognitive and neuroendocrine function: Results from a cluster randomized controlled trial of an innovative approach to the education of children in kindergarten. *PLoS ONE, 9*(11), e112393. doi:10.1371/journal.pone.0112393
[41] Sparks, S. (2014 August 20). 'Grit' may not spur creative success, scholars say, *Education Week, 34*(1), 9.
[42] Luhmann, M., Hofmann, W., Eid, M., & Lucas, R. E. (2012). Subjective well-being and adaptation to life events: A meta-analysis. *Journal of Personality and Social Pychology, 102*(3), 592.
[43] Barker J.E., Semenov, A.D., Michaelson, L., Provan, L.S., Snyder, H.R., & Munakata, Y. (2014) Less-structured time in children's daily lives predicts self-directed executive functioning. *Frontiers in Psychology, 5*, 593. doi: 10.3389/fpsyg.2014.00593
[44] Bodrova, E.B., & Leong, D.J. (2003). The importance of being playful. *Educational Leadership, 60*, 50-53.
[45] Cardichon, J. (2013). *Climate change: Providing equitable access to a rigorous and engaging curriculum*. Washington DC: Alliance for Excellent Education. Retrieved from http://all4ed.org/wp-content/uploads/2013/11/HSClimate3.pdf
[46] Shepard, L.A. (2000). *The Role of Classroom Assessment in Teaching and Learning (CSE Technical Report 517)*. Los Angeles CA: National Center for Research on Evaluation, Standards, and Student Testing.
[47] Yeager, D., Walton, G., & Cohen, G. L. (2013). Addressing achievement gaps with psychological interventions. *Phi Delta Kappan, 94*(5), 62-65.
[48] Cohen, G. L., & Sherman, D. K. (2014). The psychology of change: Self-affirmation and social psychological intervention. *Annual Review of Psychology, 65*, 333-371.
[49] Macfadyen, L.P., & Dawson, S. (2010). Mining LMS data to develop an "early warning system" for educators: A proof of concept. *Computers and Education, 54*, 588-599.
[50] Lovett, M. C., Meyer, O., & Thille, C. (2008). Open Learning Initiative: Testing the accelerated learning hypothesis in Statistics. *Journal of Interactive Media in Education*. [special issue printing top papers from the OpenLearn Conference 2008]
[51] Sitzmann, T., & Ely, K. (2011). A meta-analysis of self-regulated learning in work-related training and educational attainment: What we know and where we need to go. *Psychological Bulletin, 137*(3), 421-42.
[52] Hawkins, J. D., Catalano, R. F., Kosterman, R., Abbott, R., & Hill, K. G. (1999). Preventing adolescent health-risk behaviors by strengthening protection during childhood. *Archives of Pediatrics & Adolescent Medicine*, *153*(3), 226-234.
[53] King, A. (1994). Guiding knowledge construction in the classroom: Effects of teaching children how to question and how to explain. *American Educational Research Journal, 31*(2), 338–368.

[54] Davis, E. A. (2003). Prompting middle school science students for productive reflection: Generic and directed prompts. *The Journal of the Learning Sciences, 12*(1), 91–142.
[55] Means, B., Padilla, C., & Gallagher, L. (2010). *Use of Education Data at the Local Level From Accountability to Instructional Improvement*, Washington DC: U.S. Department of Education, Office of Planning, Evaluation, and Policy Development. Retrieved from http://www.ed.gov/about/offices/list/opepd/ppss/reports.html#edtech
[56] Gruenfeld, D.H., Mannix, E.A., Williams, K.Y., Neale, M.A. (1996). Group composition and decision making: How member familiarity and information distribution affect process and performance. *Organizational Behavior and Human Decision Processes, 67*(1), 1-15.
[57] Kollar, I., Fischer, F., & Hesse, F.W. (2006). Collaboration scripts: A conceptual analysis. *Educational Psychology Review, 18*(2), 159-185.
[58] Webb, N.M. (2009). The teacher's role in promoting collaborative dialogue in the classroom. *British Journal of Educational Psychology, 79*, 1–28.
[59] Reynolds, A. J., Temple, J. A., Robertson, D. L., & Mann, E. A. (2001). Long-term effects of an early childhood intervention on educational achievement and juvenile arrest: A 15-year follow-up of low-income children in public schools. *Journal of the American Medical Asssociation*, *285*(18), 2339-2346.
[60] Greenberg, M. T., Weissberg, R. P., O'Brien, M. U., Zins, J. E., Fredericks, L., Resnik, H., & Elias, M. J. (2003). Enhancing school-based prevention and youth development through coordinated social, emotional, and academic learning. *American Psychologist*, *58*(6-7), 466.
[61] Ming, N.C., & Ming, V.L. (accepted). Visualizing and assessing knowledge from unstructured student writing. *Technology, Instruction, Cognition, and Learning.*
[62] Ming, N.C., & Baumer, E.P.S. (2011). Using text mining to characterize online discussion facilitation. *Journal of Asynchronous Learning Networks, 15*(2).
[63] Fernald, A., Marchman, V.A., & Weisleder, A. (2013). SES differences in language processing skill and vocabulary are evident at 18 months. *Developmental Science, 16*(2), 234-248. doi: 10.1111/desc.12019
[64] Rich, M. (2014 March 25). Trying to close a knowledge gap, word by word. *New York Times*, p. A12.
[65] York, B., & Loeb, S. (2014). *One Step at a Time: The Effects of an Early Literacy Text Messaging Program for Parents of Preschoolers*. Stanford CA: Center for Education Policy Analysis. Retrieved from http://www.nber.org/papers/w20659