LRDC Internal Grants Program   *7/8/2020*

Internal Grants Program Goals:
1. *To stimulate new collaborations among Center Scientists.*
2. *To stimulate new directions for Center activity which are intellectually exciting and have the potential to be financially sustainable.*

Process: *The competition is announced in December with a RFP. Proposals are due in February; awards are made by the Executive Committee i consultation with the Director & Associate Director in April.*

PI: Indicated in Bold

Awad year[1]	Grant Title	Faculty	Grant Focus	External Funding
2008	1. The Ecology of Educational Opportunities in Pittsburgh	2008.1 **Crowley,** Knutson, Russell, with Bickel	This study examines how connections between the formal educational system and non-system actors such as informal education programs offered by museums and nonprofit organizations shape educational priorities and practices in the region. Prior educational research, including our own, has tended to look at the formal and informal worlds as separate educational systems. By mapping a regional education ecology we can look at issue, resource, and stakeholder inter-dependencies, and better understand the ways in which K-12 policy has ripple effects throughout the system. For example, Charter schools, home schooling, and the school improvement industry have begun to challenge our notions of what is a legitimate part of the K-12 system. Foundations play an important, though often invisible role, in shaping regional educational priorities. Through a set of strategically selected case studies of the relationship between the formal K12 system and informal education organizations, we will examine the	

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[1] **All grants are for a two year period unless otherwise noted**.

		following research questions: What connections between informal and formal education organizations currently exist and what are the opportunities for and barriers to robust collaboration? To what extent and how do the organizational structures and policies associated with the K-12 system shape the mission and practice of nonprofits/community based organizations? To what extent and how does the presence of nonprofits / informal education organizations shape the policies and practices in K-12 system?
2. Measuring Classroom Discussions in Mathematics & Literacy	2008.2 **Correnti,** McKeown, Smith, Stein, Ashley	The project seeks to develop reliable and valid measures of classroom discussion that can be used at scale. Additionally, the eventual goal is to convert our measurement system into an intelligent computer agent that can be used both as a tool for diagnosing teachers' capacities for leading classroom discussions and for teacher training. Classroom discussions that encourage students to construct and evaluate their own and each others' ideas and promote the development of students' intellectual authority over their ideas are associated with the quality of students' problem solving, understanding, and learning across subject areas. However, most studies of classroom discussions have been descriptive or have focused on limited aspects of a discussion. In our approach we plan to develop systems simultaneously in literacy and mathematics and discipline our work with measurement principles. Our team of five faculty members and two graduate students will work collaboratively to develop coding schemes based on videotapes and transcripts of lessons. The system will be tried out with live classroom lessons in the second year of work. Our belief is that our development process will result in clear and useful measuring tools.
3. Dialectical Interaction &		This project seeks to clarify the cognitive consequences of dialectical interaction, in which two or more people with roughly equal status but alternative viewpoints solve a problem or

	Conceptual Learning;	2008.3 **Levine** & Nokes	perform a task. We expect that the cognitive outcomes of such interaction will be strongly influenced by participants' emotional reactions during discussion. In our basic experimental paradigm, two participants receive inconsistent information on an unfamiliar topic and then discuss this issue with one of several goals (e.g., reach consensus, win a debate). These discussions are audio- and video-taped, and interactants' emotional reactions are assessed using facial signals and content-free vocal parameters of speech. In addition, we analyze the content of the discussions (e.g., number and accuracy of arguments). Cognitive outcomes of interaction are assessed using a variety of measures (e.g., recall tests, thought listing).	
2009	4. Improving Learning from Peer Review with NLP and ITS Techniques	2009.1 **Litman**, Schunn, Ashley	SWoRD is a web-based system to support peer reviewing in a wide variety of disciplinary classroom settings. One result of prior research with SWoRD is an enormous database of written materials that are ripe for analysis and exploitation in support of research on natural language processing (NLP), intelligent tutoring systems (ITS), cognitive science, educational data mining, and improving learning from peer review. In this project we will both analyze existing SWoRD-generated data, and develop an improved version of SWoRD for use in further experimentation. In particular, we will explore using SWoRD to teach substantive skills in domains involving ill-defined problems, and will explore techniques for automatically identifying key concepts and flagging issue understanding. Second, given a SWoRD toolkit of what can be accomplished robustly with peer interactions, we will explore the use of natural language processing to automatically support and improve those interactions. Finally, we will develop a new version of the SWoRD program that incorporates improved features and control facilities, and that incorporates Artificial Intelligence techniques to improve learning in a variety of ways.	*Litman, Schunn, and Ashley received a three year IES grant.*

5. Roles, Tools, and Practices of Teachers Within Inclusive Schools	2009.2 **Russell,** L.Gomez, Greeno	The education of students with disabilities in general education classrooms, often referred to as inclusion, is an increasingly popular way to organize special education programs. Yet meeting the needs of learners in heterogeneous classrooms is a challenge for educators. As school increasingly place students in more inclusive settings, teachers' roles and responsibilities are often ambiguous and undefined. This project aims to explore the roles, tools and practices employed by teachers in inclusive educational settings, and the role formal and informal organizational structures and policies play in supporting inclusive practices. Guided by community of practice and activity system theories we will study patterns of interaction in inclusive schools and classrooms. In studying activity systems lodged within formal organizational structures and subject to external policy pressure, we will also draw on and contribute to an emerging theoretical framework that seeks to integrate socio-cultural theories of learning with institutional theories of organizations. Our study will proceed in two stages. During phase one, we will conduct comparative embedded case studies of inclusive classrooms in two secondary schools implementing inclusion programs: one school with a mature inclusion program and the other in the process of transitioning from traditional self-contained special education classes to a nascent inclusion model. In phase two, we will employ a design-based approach to support the implementation of effective practices (derived from phase one) at a local secondary school.
6. School/Community Partnerships in the 21st Century: How Digital Technologies Can Build a Culture of	2009.3 **Crowley,** K.Gomez, L.Gomez	LRDC researchers are working to build a new model of school/community connections. Creating a "community school" has meant various things throughout the history of educational reform. Most recently, it has meant that the school was a place that should draw the community into its culture. But what should the early 21st century community school be like? Advances in digital technology have opened up new possibilities

	Learning That Extends Beyond		for where learning occurs, how it occurs, and who gets to be involved. The hypothesis we develop in this project is that schools should not only draw from the community, but they should be extending out to meet it. Learning should not be confined within the walls of the school. The curriculum should not be the only learning resource available to students. And teachers should not be the only adults who have learning relationships with students. In this project working with a Pittsburgh Public school called University Preparatory Academy, we will design bubbles of informal learning within a summer bridge program and in after-school time during the year. The learning experiences will use a range of robotic and computer technologies in ways that are intended promote technological fluency, allow students new ways to express themselves, and perhaps even challenge traditional notions of what we mean by learning and teaching in public schools.
2010	7. Understanding the State "Policy Pipeline": An Exploratory Comparison of States' Approaches to Race to the Top Reforms	2010.1 **Stein,** Kaufman, Russell	The federal Race to the Top (RttT) initiative contains no legislation or policy mandates for states to follow, but the program is nevertheless likely to drive all major state education reform efforts for the next decade. RttT is a competitive federal grant program that will award $4.35 billion over the next year to states that are proposing ambitious plans for four "core education reform areas": Standards and Assessments; Data Systems to Support Instruction; Great Teachers and Leaders; and Turning Around the Lowest-Achieving Schools. In order to be competitive to receive RttT grants, multiple states have already taken potentially systems-changing actions such as eliminating state charter school caps and committing to make student achievement count for 50% or more of teacher and leader evaluations. Such drastic actions foreshadow the historic education reform that is likely to occur in those states that receive RttT awards. However, we do not know with any certainty whether the diverse education reform proposals will

be enacted in ways that actually translate to real change in the "core of educational practice" (that is, in the teaching and learning that occurs within classrooms). We are engaging in an exploratory study of this timely issue examining three questions: (1) What are the theories of action implicit in successful RttT applications?; (2) To what extent is the improvement of teaching and learning central to the theories of action laid out in states' approaches to RttT reforms? and (3) What aspects of states' RttT reform initiatives are likely to be implemented in ways that positively influence teaching and learning? In the first phase of our study (Year 1), we systematically review the research literature on the relationship between state policy and school practice to develop a guiding conceptual framework and conduct preliminary analysis of all successful state RttT grant applications. We will use the conceptual framework and preliminary analysis to choose four states that will form our sample for a more in-depth study of RttT policy enactment in Year 2. Our conceptual framework and analysis of state policy enactment will seed the development of a proposal for a larger, externally-funded study of the RttT policy enactment and implementation process, taking into consideration how state context and policy enactment impact local policy implementation in districts and schools.

8. Documenting Students' Opportunities for Literate Engagement in an Afterschool Context	2010.2 **K.Gomez,** L.Gomez, Matsumura, Crowley	Our project investigates students' opportunities for participation in literacy activities while they are participants in the University Prep (UPrep) 6-12 after-school program. Informal cultures of participation, like the afterschool program, that extend students' skills and knowledge about reading, writing, design, and analysis particularly in activities and experiences beyond traditional schooling are becoming more common. Little is understood, however, about the relationship between students' participation in these programs and the development of their literacy skills and dispositions. Our goal is to address this gap in the research

and investigate the range of literacy practices available to students in these informal contexts, the degree to which students are engaged by these literacy practices and the impact of their engagement on their sense of efficacy with respect to literacy. Through our research we seek to isolate the characteristics of these activities that students find valuable, and provide information that can further the design of afterschool programs so that they can better support the development of students' literate selves.

9. Opening the Classroom: Using Data on Student Literate Practices to De-Privatize Instruction and Leverage Teacher Coordination	2010.3 **L.Gomez**, K.Gomez, Correnti	The purpose of our proposed work is to create a "boundary object" that will motivate teachers to de-privatize their practice. Such a boundary object requires the ability to make use of formative, rather than summative assessments of students. We believe, given the right information about teacher practice and student growth in literacy that teachers (across disciplines) will be more likely to engage in extended interactions regarding the development of literate practices in their students. In order to test this conjecture we will create a "data dashboard" that allows teachers in different content disciplines to "see" the literate practices of students in their other subjects. The work will proceed in two phases. First, we will develop the data dashboard which allows teachers to share information from the Mark Up Tool Suite where students can highlight text, complete reader response logs, and create summaries that can be scored by Latent Semantic Analysis. Second, we will collect repeated measures data to understand how teachers are influenced by the introduction of the data dashboard. Repeated measures will include information about the utilization of the dashboard resources, teachers' instructional practice, and student performance. Combined with case-study interviews with teachers we hope to gain insight into the process of implementing such a dashboard system on the de-privatization (and ultimately improvement) of teacher practice.

2011	10. Cerebellum and Language	2011.1 **Fiez, Schneider** (*co PIs*)	The emergence of cognitive neuroscience in the late 1980s and continued advances over the past ten years have yielded broad and highly significant insights into the neural basis of human cognition. But knowledge advances for one brain structure – the cerebellum – have not kept pace. This research will use an integrative approach that combines measures of functional activation, functional connectivity, and structural connectivity to address this knowledge gap. It will test the principle that the specific cerebro-cerebellar circuits that are engaged by a language task varies according to the type of information that must be processed to support task performance. If successful, the work should have broad theoretical impact and serve to advance basic knowledge in the field of cognitive neuroscience. The functions of the cerebellum remain a mystery despite 30 years of debate, and the emergence of human connectivity data would represent a major step forward.	
	11. Keeping Instructors Well-Informed in Computer-Supported Peer Review	2011.2 **Ashley,** Litman, Wang, Schunn	From the instructor's viewpoint, a class writing assignment is a black box. Until instructors actually read the first or final drafts, they do not have much information about how well the assignment has succeeded as a pedagogical activity, and even then, it is hard to get a complete picture. Computer-supported peer review systems such as SWoRD, a scaffolded peer review system can help students to write higher quality compositions in classroom assignments, can help in this regard. The goal of this project is to develop and evaluate methods to provide instructors with a comprehensive overview of the progress of a class writing assignment in terms of how well students understand the issues based on structured reviewing rubrics, feedback students provide and receive in the peer review process, and machine learning computational lingustics analysis of the resulting texts. The SWoRD-based peer-review system will present the instructor's overview via a kind of "Teacher-side	*Litman received a 2014 Google Research Award entitled Peer Review Search & Analytics in MOOCs via Natural Language Processing.*

Dashboard" that will summarize salient information for the class as a whole, cluster students based on common features of their texts, and enable instructors to delve into particular student's writings more effectively in a guided manner.

12. Preparing to Assess the Influence of Classroom Practices on Student Outcomes in 'Traditional' vs 'Reform' Approaches to Mathematics Instruction	2011.3 **Stein,** Smith, Munter	Debates about how mathematics is learned and how it should be taught in schools have been ongoing for the better part of a century. But it was in the mid- to late-1990s, after the publication of the National Council of Teachers of Mathematics first Standards document and the development and implementation of a number of National Science Foundation (NSF)-funded 'reform' textbook series, that the "math wars" began to rage. Although it is not being waged with such fervor as at the beginning of the 21st century, the debate remains unresolved. This project will propose a list of activities that to prepare the way for soliciting a large federal grant to conduct a randomized controlled trial to compare the effects of reform mathematics instruction with those of traditional instruction. To date, such research has been framed primarily as a comparison of textbook series. In 2004, the National Research Council concluded that, across all such studies, insufficient evidence existed for declaring any one program effective. Since then, a few researchers have attempted to contribute stronger evidence.
13. Theoretical and Architectural Support for Mobile Group Learning	2011.4 **Wang,** Schneider, Levine	Mobile phones and portable internet tablets have become the most popular computing devices in human history. Mobile devices are changing the ways that we complete our daily tasks and interact with people in the same way PCs have in the past thirty years. The high penetration rate of mobile devices provides both challenges and opportunities in learning. On one hand, researchers have been exploring the usage of mobile phones and PDAs as new education vehicles and numerous publications have been created; On the other hand, many

mobile learning projects treat mobile devices as "smaller/cheaper PCs" and a major portion of research efforts focus on porting the existing educational applications for PCs to mobile devices, hence enabling "education anytime, anywhere". Interestingly, the emergence of several "killer applications" in the mobile space does show that when designed properly, mobile applications can engage, motivate and entertain users in ways that are not possible on desktop computers. At least three common themes show up in almost every successful application - first, the introduction of social dynamics in the application logic; second, the active usage of context information (location, time, nearby people); third, proper incentive mechanism. In this project, we will analyze successful mobile social applications and games and document lessons and insights in this new field via design patterns. Such efforts will aid practice by speeding up the diffusion of new interaction techniques in mobile learning and presenting the information in a form more usable to educators. We will design and implement key architectural support for enabling mobile group learning applications, making it easier and faster to build high quality, domain-specific mobile group learning systems. Based on the platform we create, we plan to design, build and evaluate at least one group-based mobile learning application. Such efforts will allow us to do "learning by doing" and start iterating the implementation by running some small scale deployments.

2012			*Due to university-wide budget cuts, no projects funded in 2012.*
2013	14. Investigating Adolescent English Learners Interactions with	2013.1 **McKeown,** Crosson	The purpose of the proposed project is to investigate adolescent English Learners' (ELs) interactions with academic language. Findings from this project will inform development of an instructional intervention that will support ELs' effective learning of academic English vocabulary. This represents a new direction

	Academic Language		of research to incorporate consideration of EL's needs and resources within a long-standing program of research on vocabulary learning and instruction.
	15. Response-to-Text Prompts to Assess Students' Writing Ability: Using Natural Language Processing for Scoring Writing At-Scale	2013.2 **Correnti,** Litman, Matsumura	The specific questions we address in this study are as follows: 1) How can we use NLP to automatically code student essays for all five dimensions of RTA, taking advantage of both human-coded essays and protocols for training human coders? What is the level of agreement between AES- and human-coded RTA ratings? How do AES- and human coded ratings compare on substantive dimensions of the RTA assessment (the quality of students' inferences and the evidence marshaled to support their assertions)? Can we achieve AES performance levels for substantive dimensions that are competitive with holistic AES performance? Qualitative analyses also will be undertaken with both 'easy' and 'hard' to score essays to explicate the features of responsesthat are difficult to score using AES. 2) After adjusting for student demographic characteristics and prior achievement how much variance exists between classrooms for AES-coded ratings? How does this compare with human-coded ratings? 3) What is the relationship of human-coded and AES-coded ratings to teaching practices requiring student reasoning and extended writing? We will examine univariate and multivariate hierarchical linear models (Raudenbush and Bryk, 2002) similar to those in Correnti, Matsumura, Hamilton and Wang (in press).
2014	16. Improving Undergraduate STEM Education by Integrating Natural Language Processing	2014.1 **Menekse**, Litman, and Jingtao Wang	One of the main goals in this project is to develop a continuous cycle of student reflection and instructor feedback with supporting technological tools. Reflection is a fundamental learning activity in which people "recapture their experience, think about it, mull it over and evaluate it" (Boud, Keogh, & Walker, 1985). Although some students intuitively engage with self-reflection, a majority of students need external support to

with Mobile Technologies		reflect (Menekse et al, 2011; Zimmerman, 2002). Without some guidance and feedback, reflection can become disparate so that expected outcomes may not emerge (Boud & Walker, 1998). Studies have shown students' learning improves and their conceptual understanding deepens when they receive targeted and timely feedback (e.g., Butler & Winne, 1995). The specific research questions we address in this project are as follows: 1) How does a continuous cycle of students' reflection and instructor feedback affect learning outcomes and course retention rates in undergraduate Physics courses? 2) How can we use NLP to create relevant and coherent summaries by using students' reflections? What is the level of agreement between human coders and automated algorithms to create summaries? Can thecapabilities of mobile devices provide useful information for optimizing the summaries? 3) How can we design effective mobile interfaces to collect high quality reflections and improve students' response rate? What are the best methods to design an effective instructor side visualization interface to browse, navigate the reflections collected, and interpret results from NLP algorithms? In this project, we will collaborate with Dr. Chandralekha Singh to implement our study in her *Physics for Science and Engineering* class. Dr. Singh is not only a LRDC center associate but also serves as the director of the Discipline Based Science Education Research Center (dB-SERC), so the proposed work also represents a new collaboration between LRDC and dB-SERC.
17. Innovating Moti-vation Research:In-sights from Urban Middle School Classrooms on the Links between	2014.2 **Nokes-Malach,** Wallace, Greeno, Correnti	Over the past 40 years much progress has been made in understanding how student cognition and motivation affect learning and achievement outcomes (e.g., Blackwell, Trzesniewski, Dweck, 2007; Dunlosky, Rawson, Marsh, Nathan, Willingham, 2013). However, the vast majority of this work has focused on the cognitive and motivational factors that occur at the level of the individual student, which misses the on-going

Psychosocial Classroom Activity and Mathematics Learning	social processes that may play a large role in driving both student level motivation and achievement outcomes (McCaslin, 2009). In the current proposal we aim to address these gaps in the literature by developing a research program to a) identify cognitive, competence, and autonomy support factors at the classroom level, and b) examine how various configurations of these factors (i.e., psychosocial support profiles) relate to student learning and achievement. To do this we will analyze classroom video data to assess classroom activities in which teachers provide (or do not provide) particular kinds of support. We will use videos from the Measures of Effective Teaching (MET) longitudinal database that contains over 1,000 videos from 761 different 6 – 9 grade mathematics classrooms and includes student level learning, achievement, and motivation data. A central goal of this project is to develop a theoretical framework and research paradigm to integrate situative and sociocultural perspectives on how social processes afford and constrain participation with information processing views on individual skill development in a way that leads to new explanations and predictions. We focus on urban settings in which understanding the role of the classroom motivational climate may be particularly important to understanding the conditions necessary to support student learning and achievement (Boykin & Noguera, 2011). This work brings together researchers from different theoretical perspectives and methods (Wallace from an urban education and sociocultural view, Greeno from a situative view, Nokes-Malach from a cognitivist view, and Correnti from a systems-level view) to work towards these integrative goals.
18. The Dangers of Computation without Quantitative Meaning: Testing the Case of	According to the National Council of Teachers of Mathematics, students in pre-K through grade 12 should be instructed to understand the meaning of number symbols and operations,

	Symbolic Estrangement	2014.3 **Libertus,** Fiez, Schunn	and be fluent at mathematical computations. However, over the past 30 years, the gains in children's mathematics achievement in the US have been largely limited to the elementary grades (NAEP, 2013). One potentially important but understudied factor for the stalled progress in secondary education may be "symbolic estrangement", which is the poor integration of numerical symbols with underlying representations of quantities, such that mathematical computations dependent heavily on learned fact retrieval and procedural strategies. This proposed work brings together for the first time Melissa Libertus' expertise in ERP methodology with Julie Fiez's expertise in fMRI and Chris Schunn's expertise in behavioral measuresand bridges basic research and application. Specifically, we propose to develop *convergent* behavioral and neuroscience methods to characterize differences in the quality of symbol-quantity integration and link these markers to differences in math achievement in college students. The critical aspect of the current project is to show converging results across each of the methods that we will use to measure symbolic integration.
2015	19. Tell Me About Math: A Longitudinal Training Study on the Effects of Parent-Child Interactions and Parental Cognition on Children's Math Abilities	2015.1 **Libertus, M.**, Libertus, K.	Innovations in the sciences, technology, engineering, and mathematics (i.e., the STEM disciplines) have yielded about 50% of the economic growth over the last 50 years [1], but recent international comparisons placed the US well below OECD averages and far behind emerging and leading economies such as Taiwan, South Korea, Japan, and Switzerland [2]. Consequently, it has been suggested that the US needs to improve its math education to remain competitive [3]. Already at school entry, children differ dramatically in their math abilities [4, 5] and this gap widens with increasing age [6]. To close this achievement gap, we need to examine the origins of individual differences in young children's mathematical understanding so we can provide parents and early childhood educators with

guidelines and recommendations to ensure that children enter school with the skills necessary to succeed in math [7]. The proposed study will examine the relations between the basic number skills and math abilities in parents and their preschool-aged children and how parents' basic number skills and math abilities influence their informal STEM learning activities with their children – a known predictor of future math abilities. This project will for the first time combine Dr. Klaus Libertus' expertise in longitudinal training studies in early childhood, his recent methodological advances in remote assessments via video chat, and his focus on parent-child interactions with Dr. Melissa Libertus' expertise in the development of children's mathematical thinking in early childhood.

20. Facilitating a Common Core Approach to Argumentation with Diagramming and Peer Review	2015.2 **Ashley,** Petrosky	The Common Core State Standards (CCSS) for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects [6, p.5] focus on argumentation. "Consistent with NAEP, the overwhelming focus of writing throughout high school should be on arguments and informative/explanatory texts." See [33, p. 10]. In preparing written arguments, authors must communicate a position, claim, or hypothesis, use it to anchor the framework of reasons and evidence presented; they must also integrate others' arguments and anticipate counterarguments and critiques and possibly refute them [9; 17; 21; 34] or reconcile the arguments and counter arguments and synthesize a new approach [4]. The Problem: High school students have difficulty with argumentative writing and often fail to achieve competence [22; 4]. The CCSS argumentation standards define a set of criteria for good written argumentation tailored to the progressive stages of argumentation that high school students can and should experience. In attempting to apply the CCSS argumentation standards in a high school environment, however, problems have emerged. It is not clear that high school students or their teachers necessarily

		understand these argument-related elements, relationships or operations.
21. Informal Learning about Traumatic Brain Injury	2015.3 **Crowley,** Schneider	We propose a new research collaboration to develop informal learning experiences for high school football players, coaches, and parents focusing on traumatic brain injury (TBI). Our goals include (1) exploring science communication design principles that encourage STEM learning and positive health decision making in real world settings, (2) developing, deploying, studying, and, eventually, scaling programs that change athletes' understanding of the causes, consequences, and treatments of TBI, and, ultimately, (3) reducing the rate of serious TBI among high school football players in Western Pennsylvania and beyond. The project begins with Walt Schneider's recent scientific work to understand and visualize how the brain recovers from TBI -- a blow or jolt to the head that disrupts the normal function of the brain. Our approach to developing interventions is based on Crowley's recent work on informal learning and climate change. Similar to TBI, climate change is a problem where short-term actions have long term and poten-tially catastrophic consequences. Yet even when people under-stand the basic principles of climate change, they often make personal decisions that are not adaptive. The literature suggests that, in many real-world decision making contexts, scientific knowledge is not enough to support action (Allen & Crowley, 2015; Crowell & Schunn, 2013). Instead, messages about climate change are most effective when designed around the principles of participation, relevance, and inter-connected-ness (S. Schneider, et al. 2014)—principles that situate climate change knowledge in the daily social interactions, emotions, and values of learners and communities. Successful informal learning about climate change needs to focus on changing the culture around personal decision making, not just the decision making of any one person. We will believe a similar approach is needed for TBI.
22. Attentive, Bidirectional		

16

Mobile MOOC Learning via Implicit Physiological Signal Tracking	2015.4 **Wang, J.**	Learning at scale is challenging in both traditional large classrooms and massive open online courses (MOOCs). This is in part due to the reduced attention each student receives and the lack of fine-grained feedback to instructors on students' learning activities. Video materials (e.g. lecture videos, supplemental tutoring resources, screencasts) can play a crucial role for both learning new topics and disseminating existing knowledge in large classrooms, flipped classrooms (read/watch online first, then discuss in class), blended classrooms (mixtures of online and traditional class formats), and MOOCs. However, it is hard to know how video material was consumed, whether students were challenged or distracted during the learning process. Teachers in large classrooms or MOOCs face at least three major challenges: 1) Students lack the sustained motivation to complete the many activities involved in a full course when students feel anonymous in a sea of learners or when students are learning alone via technology. 2) Most large courses are primarily uni-directional, i.e. from instructors to students. As a result, instructors have. 3) There is little individualization of instruction. By leveraging unique affordances of mobile devices, and our recent research innovations [6, 9, 20], we propose to create a new mobile learning system named AttentiveLearner, a simple yet elegant solution to track students' mental states (including but not limited to attention, mind wandering, and boredom) during MOOC learning, flipped classroom learning, and blended learning on unmodified mobile phones via implicit physiological signal tracking.
23. Using Psychosocial Approaches to Promote African American Adolescents' STEM	2015.5 **Wang, M.,** Binning, Huguley	Efforts to broaden participation in STEM careers have been hampered by racial disparities in STEM preparation and achievement that arise in middle school (NCES, 2009). The present proposal aims to address racial disparities with African American middle school students by synthesizing different

	Identities and Persistence		promising psychological interventions in both middle school and college settings for promoting STEM identities, performance, and persistence for this population. We begin from the premise that patterns of underachievement by African Americans in STEM fields are at least partly traceable to the socio-historical and psychological conditions that these students encounter, which White students largely do not. Our synthesis of the literature concludes that certain psychosocial interventions at the middle school level have shown promise for addressing educational racial performance gaps, but have not focused specifically on STEM learning. Meanwhile, a different set of successful STEM interventions at the collegiate level have focused on STEM outcomes, but they have not been applied to adolescents during middle school, a critical period for the formation of both racial identity and STEM-related identification (Nasir & Hand, 2008). There is also a continued need to better understand specific and often subtle factors that support African American youth participating in collegiate STEM programs.
2016	24. Using Natural Language Processing to Study The Role of Specificity and Evidence Type in Text-Based Classroom Discussions	2016.1 Litman, Godley	How do students learn through text-based discussions in English Language Arts (ELA) classrooms? This study seeks to examine the content of student talk during ELA discussions in order to better understand how students develop their understanding of texts and reasoning skills through discussion. Our proposed study uses Natural Language Processing (NLP) to analyze two important features of students' discussions about texts: specificity and type of evidence.
	25. Uniting Cognitive and Motivation Science: An Opportunity Cost Model of Self-Regulated Learning	2016.2 Fraundorf, Galla	Students make bad study choices. They highlight and re-read notes when they should test themselves, and they cram the night before an exam rather than study over time. What explains such poor choices? The prevailing view in cognitive psychology [1–3] is that students are ignorant of what constitutes effective study. We propose and test an alternative explanation: Good strategies are too effortful given competing leisure activities,

			such as social media or hanging out with friends. This view is rooted in the interdisciplinary nature of the PIs' backgrounds and unites cognitive and motivational science in a novel and integrated perspective on self-regulated learning.
2017	26. Integrating fMRI and EEG to Examine Learning and Memory Consolidation	2017.1 **Coutanche,** Tokowicz	To effortlessly recognize the words on this page today, your brain has achieved several remarkable feats. Starting with the first few times that you encounter a specific word form, object or concept, our brain transforms it from a fleeting perceptual experience to a stable memory trace that can be reactivated at will. A central component of this learning process is memory "consolidation" – a process that stabilizes a new memory trace, and integrates it with existing lexical, perceptual, and semantic knowledge. Our understanding of the connection between initial learning process, and later consolidation, has been limited by the fact that these two important parts of the broader learning process have typically been studied separately and with different neuroscientific methodologies. In the proposed study, we plan to advance our understanding of learning and memory in ways that could not be achieved before, by combining the neural data recorded through fMRI and EEG within the same experimental protocol.
	27. How Low-and high-SES Parents Support Young Children's Mathematical Thinking *(extended to June 2020)*	2017.2 **Libertus,** Bachman	Socioeconomic disparities in math skills have grown in recent years, as the math skills of children at the upper end of the income distribution have grown faster than those of children from middle- or low-income families. The income achievement gap grew 40% between the 1970's and the 1990's, so that today it is almost twice as large as the black-white achievement gap [1]. SES gaps in math skills first emerge in preschool [2, 3] and by the start of kindergarten the disparity in math skills between low socioeconomic status (SES) children and their higher income peers is 1.3 standard deviations [4]. These differences are maintained as children progress through school [5]. Critically, SES-related disparities in math skills have implications for long-

			term achievement and educational attainment in adulthood [6, 7]. Thus, there is an urgent need to disentangle the mechanisms underlying SES disparities in math skills before children start kindergarten. Specifically, we need to delineate the proximal experiences driving socioeconomic disparities in math skills in the home environment during early childhood.
2018	28. Examining How Metacognitive Knowledge Intervention Can Facilitate Digital Literacy: An Experimental Study of College Learners *(extended to December 31, 2020)*	2018.1 **Cho**, Fraundorf	Digital literacy is central to success in college, career, and life. However, many students fail to successfully read, write, and think in Internet environments because they lack appropriate thinking strategies for the nebulous space of the Internet, in which an unprecedented number of information sources need to be located, evaluated, and integrated. These metacognitive and digital literacy skills are often missing in current literacy curricula, so there is a critical need to identify approaches to instruction that would prepare students for an increasingly complex knowledge society. In this project, we develop and test a metacognitive intervention to support college students' Internet inquiry on a socio-scientific issue and their strategic processing of digital sources of information. We hypothesize that student performance can be enhanced with metacognitive knowledge of what, how, and especially why literacy strategies work in the digital environment. The goals of our project are rooted in the interdisciplinary nature of the PIs' background in literacy education and cognitive psychology: First, we test the predictions of learning theories about what kinds of metacognitive knowledge are most relevant to digital literacy performance. Second, we seek scientific evidence on the most pedagogically effective ways to enhance metacognition in education and digital literacy. Ultimately, we aim to acquire insights to creating a prolonged, sustainable approach to teaching learners the high-level literacies required for learning in the digital age.

29. A Bayesian Approach to the Study of Conceptual Change *(extended to August 31, 2021)*	2018.2 Kuo, Rottman, **Nokes-Malach**	Learning scientific concepts is difficult because students may possess intuitive beliefs (often labeled "misconceptions") about how the world works that contradict these concepts (Champagne, Klopfer, & Anderson, 1980; McCloskey, 1983). The dominant view in the conceptual change literature is that incorrect, naïve beliefs form a coherent, theory-like structure. This coherence view has primarily been developed in cognitive psychology. Others have described conceptual knowledge as a network of fragmented conceptual elements. In this network view, conceptual reasoning is the co-activation of certain pieces of this conceptual network. Central to the network view is the idea of an activation weight – the likelihood that each conceptual element will be invoked in a particular situation. Although the debate between the coherence and network views of conceptual change has continued for more than 25 years, progress toward a resolution has been slow. Advancing this debate will require methodological innovations for "more precise coordination between models and evidence" (diSessa, 2006, p. 278). To address this goal, we propose a program of research aimed at developing a new experimental methodology for the network view of conceptual change. To accomplish this, we will draw on theory and methods from probabilistic/Bayesian theories of learning and reasoning. Crucial for our purposes, probabilistic/Bayesian methodologies have well-established paradigms for the measurement and analysis of probability weightings. We will adopt these paradigms, proposing an experimental methodology for the network view that uses probabilistic judgments of certainty to measure the activation weights of conceptual elements. The proposed research program begins an exploration into the synergies provided when taking a probabilistic/Bayesian approach to conceptual change. The principle outcome of this work will be an experimental methodology – featuring the Justification-Certainty sequence – that is consistent with the network view of conceptual change.

2019	1. Income Dynamics and Adolescent Development: Understanding Behavioral and Academic Disparities Through Dense Sampling of Income, Parenting, and Perceptions	2019.1 **Hanson, Miller,** and Votruba-Drzal	This study examines that economic disadvantage poses a significant threat to positive youth development. Compared to their more affluent peers, poor students are at increased risk for lower achievement, chronic school absenteeism, school dropout, and problems with anxiety, depression, conduct disorder, and other mental health issues. Understanding the links between income dynamics (i.e. income level and volatility) and adolescents' academic and behavioral functioning is critical because these income-related gaps translate into lower educational attainment, economic instability, and mental and behavioral health problems in adulthood. However, extant research on income's associations with youth development has ignored monthly and biweekly income fluctuations, which are particularly high among low-income families, and may be the most psychologically meaningful driver of family stress. Moreover, this project examines family income dynamics' associations with parental stress and behavior and adolescents' perceptions of family financial stress. Additionally, it considers whether these processes exhibit direct and indirect links with adolescents' school performance and behavior problems.
2019	2. Using Human Intracranial Recordings to Examine the Spatiotemporal Dynamics of Symbolic and Non-Symbolic Number Processing	2019.2 **Libertus,** Ghuman	The ability to manipulate numerical information is critical for a wide range of daily activities, from rapidly estimating the number of objects in our environment to performing formal mathematics with number symbols. According to the triple code model, the neuroanatomical correlates of number processing typically encompass three regions: a region in the left superior temporal sulcus that supports the verbal representation of numbers, the intraparietal sulcus (IPS) in posterior parietal cortex that is involved in representing analog magnitude information related to non-symbolic number formats such as dot arrays, and a less well-established subregion in ventral temporal cortex (VTC) – a putative visual number form area that has been proposed to represent the visual form of symbolic numbers such as Arabic numerals. Several

recent studies using functional magnetic resonance imaging (fMRI) and intracranial encephalography (iEEG) recordings suggest a broader role of VTC in numerical cognition. In addition to representing the visual form of Arabic numerals, subregions within VTC respond to a larger range of visual number formats such as dot arrays and number words in contexts that require magnitude processing, such as arithmetic operations. Furthermore, these number-sensitive VTC regions demonstrate relevant structural and functional connectivity with IPS during math tasks. Thus, the goal of our proposed collaboration is to leverage our combined expertise with highly spatiotemporally resolved iEEG recordings and mathematical cognition to describe the neural dynamics in VTC and IPS that underlie symbolic and non-symbolic number processing.

| 2019 | 3. Studying Collaborative Dialogue with a Teachable Robot in a Computational Thinking Domain | 2019.3 **Walker,** Litman, and Nokes-Malach | This project seeks to analyze how individuals, dyads, and triads of learners interact to teach a robot about computational thinking. Learning by teaching interactions, where students explain concepts to other people or to intelligent agents, have been shown to foster improved learning, both through cognitive mechanisms and social mechanisms.
While these mechanisms have been explored in either human-human collaborative groups or human-agent dyads, this project takes a step forward by examining how these interactions unfold in more complex scenarios involving collaborative learning groups with intelligent robots (i.e., an intelligent agent with a physical presence). We will improve understanding of how lower-level features of interaction that can be computed using automated methods predict higher-level cognitive and social properties that can be manually coded with high reliability. We will then investigate whether these cognitive and social properties are associated with improved learning and motivational outcomes. Intelligent robots have the potential to enhance learning by responding adaptively to learners to provide help, engage in conversation, or even provide motivational encouragement in the face of impasses. In this project, we are interested in positioning the robot as a tutee that one or more human learners teach about a subject domain using spoken |

dialogue. When teaching an agent, much like when teaching a human, students attend more to the domain, and reflect and elaborate on their own knowledge as they formulate explanations. If students experience successes when teaching, they may build self-efficacy in the subject domain. Using a robot instead of an agent has been shown to produce additional social and learning benefits due to its physical affordances. This project proposes to build on existing learning sciences work within the exciting research spaces of teachable agents, human-robot interaction, spoken dialogue interaction, and collaborative learning, by examining a more complex scenario: multiple students collaborate with a robot through spoken interaction.