eDGE: eSTEM Designing Games for Education

eMINTS National Center
University of Missouri
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Introduction

A profound lack of diversity pervades the computer science (CS) workforce (Code.org, 2020). Women in computer-related industry jobs today comprise 22% of workers, which is equivalent to the percentage of workforce participation in the 1960s. With racial/ethnic minorities comprising only 13% of the computer industry workforce, minority females are but a small fraction of those workers (Code.org, 2020). Underrepresented students (rural, female, black, Latino, Native American, and low income) are of greater concern with very few entering CS careers at a time when technology rules our lives to the point of determining the very news and advertisements we are encouraged to view (Ellice, 2020). Besides a 21st century diverse workforce need, CS skills increase problem-solving abilities and interest in college enrollment (Salehi et al., 2020). Previous studies have been conducted on CS education, but few have attempted to measure their capacity within the core curriculum (Wangenheim, 2017). Many studies are conducted in classrooms where CS is a stand-alone subject (Pazinato & Teixeira, 2013; Wilson & Moffat, 2010; Aureliano & Tedesco, 2012).

Projects such as the K–12 Computer Science Framework suggest encompassing students interests and abilities in afterschool, summer, or one-time projects (i.e., Hour of Code), which reports an increase in student enthusiasm but lacks the broad impact for CS or STEM career aspirations (CSTA, 2018). For wide-range impact, the CS program must become an integral part of the core classrooms at an early age, encouraging girls and underrepresented students to pursue CS careers, alleviating the shortage and expanding diversity in the field of STEM (Shein, 2019). With the stakes so high, failing to provide opportunities to rural, low-income, and under-represented students is no longer an option, but Common Core School Standards (CCSS) and testing initiatives have left little time in the school day for electives or enrichment (Ellice, 2020).

The pressure is real for schools to meet the CS standards and prepare students for the future, but the challenges are just as real.

The eDGE Model Impacts Learning by bringing CS into the core classroom for all 5th grade students. The two teacher courses, Game Design and Simulation Creation, are built from a foundation of proven Scalable Game Design (SGD) practices (NSF, 2018) and research based eMINTS student-centered pedagogy and coaching (Meyers, 2016). eDGE brings these computational thinking and programming skills to teachers and students, while requiring ***no previous*** computer science experience through SGD (Repenning, 2015).

Quality of the Project Design

How do we support and sustain upper elementary teachers in using CS education curricula with their core content in ways that support synergistic goals for computational thinking and STEM education? eDGE proposes to infuse computer science and mathematics education with computational thinking (CT) so that computer science and mathematics are more integrated, relevant and interesting for all students and allow core teachers to choose content rich materials for their classrooms. Given the historical origins of computer science as mathematical inquiry, it makes sense that early computer science activities should be situated in mathematics lessons as integrated STEM approaches for logic, problem solving, and making sense of mathematical content.

Goals, Objectives, and Outcomes

Table 1 outlines the 4 project goals and accompanying objectives and measures**: 1)** develop a replicable model for CS education in core STEM content areas, **2)** increase teacher efficacy and effectiveness addressing increased CS standards within core STEM content, **3)** increase student CS knowledge and skills, and **4)** increase student efficacy with an interest in CS.

Table 1. Goals, Objectives, and Measures	
Phase 1 - Develop and Refine eDGE Model (Years 1 - 3)	
Goal 1 - Develop a replicable model for CS education in core STEM content areas	
Objectives	**Measures**
1.1 Develop project processes and PD materials that support teachers' use of CS education in core classroom curriculum 1.2 Prepare and implement a successful formative pilot study 1.3 Use evaluation input to inform iterative improvement of eDGE PD and coaching 1.4 Revise existing fidelity measures and create new measures for coaching	M1.1 Project records & coach logs M1.2 Project records & coach logs M1.3 Teacher and coach interviews, teacher survey, CTP assessment of student artifacts, classroom observations M1.4 Project records & coach logs
Phase 2 - SRI Efficacy Study (Years 3 - 5)	
Goal 2 - Increase teacher efficacy and effectiveness addressing CS standards within core STEM content	
Objectives	**Measures**
2.1 Intervention teachers increase their use of inquiry strategies that integrate CS skills as indicated by surveys, interviews, Look Fors, and SCOPE 2.2 Increase the use of student-centered and guided discovery instructional strategies as indicated by SCOPE	M2.1 Project records & coach logs M2.1 Teacher and coach interviews M2.1 Teacher survey M2.1 Classroom observations using eDGE Look Fors M2.1, 2.2 Classroom observations using SCOPE[1]
Goal 3 - Increase student CS knowledge and skills - SRI	
Objectives	**Measures**
3.1 Increase CT as measured by Principled Assessment of Computational Thinking	PACT[2] (Principled Assessment of Computational Thinking)
3.2 Increase programming skills as measured.	Student survey CTPA
Goal 4 - Increase student efficacy with and interest in CS - SRI	

Objective	Measure
4.1 Students report increased interest in CS careers and electives as indicated by the motivation survey.	M4.1 Student motivation survey (SMS)[3]

[1] Webb, D. C., Miller, S. B., Nickerson, H., Grover, R., & Gutiérrez, K. (2014). *Student Centered Observation Protocol for computer-science Education* (SCOPE). Boulder, CO: University of Colorado at Boulder.
[2] Snow, E., Rutstein, D., Basu, S., Bienkowski, M., & Everson, H. T. (2019). Leveraging evidence-centered design to develop assessments of computational thinking practices. *International Journal of Testing*, *19*(2), 103-127.
[3] Webb, D. C., & Miller, S. B. (2015, April). Gender analysis of a large scale survey of middle grades students' conceptions of computer science education. In Proceedings of the Third Conference on GenderIT (pp. 1-8).

Extent of Project Design to Address Needs

The eDGE project is designed to address needs of rural schools by using a variety of modalities to support learning. Teachers complete training in two 6-week online, self-paced, facilitated courses with ongoing virtual coaching and peer support. In this proven PD format (NSF, 2018), teachers will learn CS education and ways to promote computational thinking with the support of a coach who is actively monitoring their progress. With student programming occurring in online, browser-based environments, teachers have options to support student learning in face-to-face, hybrid, or remote learning contexts; the use of various learning modalities reduces learning interruptions if remote teaching becomes necessary or if students need to work on projects from home (Webb, 2017). The eDGE courses provide ***lessons and materials*** and show teachers how to scaffold student learning, practice strategies, encourage peer tutoring, and support cooperative problem solving, which are the basis of the highly successful eMINTS pedagogy that meets the What Works Clearinghouse without reservations guidelines (Meyers, 2016) in many rural school settings.

The eDGE model incorporates eMINTS and SGD design principles with a focus on best practices involving authenticity, problem solving, collaboration, and computational thinking (CT). The SGD community-based guided discovery is a process of collaborative student-centered learning with facilitated teacher guidance, which aligns to the eMINTS Instructional Model (eIM; Appendix I.1) and has shown high positive indicators for sustainability and scalability. Participating teachers not only implement what they learn in PD courses but continue beyond requirements of the project by working with additional students (Repenning, 2015). All students respond well to the SGD curriculum and pedagogical approaches, demonstrating high levels of motivation to take additional classes in game design. Research on SGD outcomes found that after students completed even just one project unit, 74% of boys and 64% of girls (100% in some schools), 71% white and 69% minority students, were interested in pursuing more computer programming activities (Webb, 2015). SGD uses Project First principles, starting with designing a game (like Frogger or Pacman) to motivate student learning of computational thinking patterns (CTP). In turn, students apply these CTPs in STEM simulation projects with Just-In-Time learning where they are "presented with problems in a fruitful order, getting initial problems that set up good generalizations for later problems" (Gee, 2007, pg. 2). The eDGE model incorporates the ***proven research strategies of eMINTS and SGD*** to create an optimal learning environment for high needs schools (Chaffin, 2015). Once students approach mastery of CTPs, as determined by the CTPA tool (Appendix I.2), they readily transfer the coding patterns for CTPs to other programming languages, whether text-based or visual. This is the power of the eDGE model. Adding coaching to increase effectiveness will add to our understanding of what support core elementary teachers need for CS education, considering the shortage of CS-ready teachers in rural schools.

Fig. 1 eIM

Current Research of Effective Practices Around CS

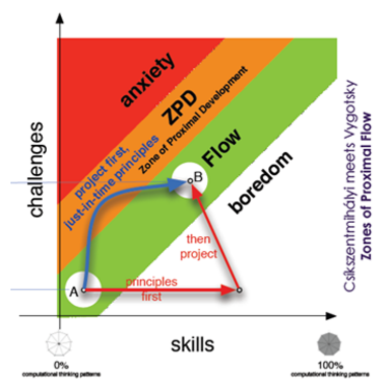
eMINTS and SGD have a strong history of helping schools improve achievement for high-needs students. In all studies from 2002-2009, for all subjects, the achievement gap between eMINTS and non-eMINTS students by group (special education status, FRL, and race/ethnicity) was statistically significant and grew over time (Meyers, 2015). "The fact that the effects were most dramatic among the highest-need students suggests that the kind of environments eMINTS teachers create in their classroom may be particularly effective for these students" (Strother et al., 2006, p.7). eMINTS incorporated these principles into the oDREAMS, CS4HS, and CT4TC projects in partnership with the University of Colorado Boulder using SGD. Integration of programming activities into mandatory courses resulted in high female (45%, n > 8000) and underrepresented minority student participation (48% of participating students), and high levels of student motivation to take another game design class.

For CS education to meet the needs, it must become rooted into public schools at the core level, beginning as early as elementary school (Du & Wimmer, 2019). In one study, females outperform males in programming comprehension following an Hour of Code tutorial and moved from a negative view of CS to a more positive view. However, these highly capable students may be steered away from STEM careers due to low efficacy in their ability as perceived by themselves and their teachers (Phillips, 2017). Early exposure to CT skills will give students confidence, increase problem solving ability, and positively affect STEM career choice (Hamlen, 2018; Salehi et al., 2020). Research shows incorporating CS and STEM into the core curriculum encourages students who may not typically choose CS or STEM related courses to seek out more of these opportunities (Repenning, 2016).

Absolute Priority 2: eMINTS is an exceptional field-initiated innovation. Most PD programs attempt to improve specific aspects of effective teaching, such as standards-based lesson design, data-driven decision making, differentiation, inquiry- or project-based instruction, collaborative learning structures, and technology integration; few, however, incorporate a comprehensive approach to 21st century skill development to the extent that the eMINTS program does (Meyers et al., 2016). eMINTS trainers provide coaching to help teachers reflect on their own teaching practice and become self-sustaining decision makers (Foltos, 2007) while promoting the critical skills of creativity, communication (persuasion), collaboration, and adaptability (NACE, 2020). eDGE provides flexible teacher PD to bring CS and STEM into core classrooms where all students can experience the learning.

SGD, as a proven field-initiated innovation, breaks programming down into semantic chunks of visual representations and code -- i.e., Computational Thinking Patterns (CTPs). CTPs are concepts that all programmers must learn and master, such as: if-then, push, pull, transport, generate, cursor control, diffusion, collision, loop, hill-climbing, and more. By using these concepts to design, program, and debug games, students internalize and transfer these CT skills while ***meeting or exceeding*** CS standards. Students begin with Frogger, progress to Pacman and advanced Pacman (with use of collaborative diffusion to provide the ghosts artificial intelligence), and then to scientific simulations. Beginning with games while building skills makes learning to code fun and engaging. Students use the CT skills they learn in game design to create simulations involving higher-level thinking (Koh, 2012). Each progressive programming project is designed to be motivating and engaging while keeping students in a *Zone of Proximal Flow* (Fig. 2)*,* or *flow* state (Basawapatna, 2013), a theory of motivational curriculum design and enactment that incorporates Vygotsky's Zone of Proximal Development (1978) and Csíkszentmihályi's State of Flow (1990).

eMINTS and SGD have a track record of collaboration that has specifically improved achievement in rural school contexts. eMINTS' 2010-2015 i[3] grant randomized controlled trial of 60 high-needs middle schools in rural Missouri found significant changes in teacher practice and student achievement in mathematics on state assessments. Teachers participating in eMINTS' PD demonstrated increased skills in the domains of positive community of learners (effect size of .24), inquiry-based learning (effect size of .73), high-quality lesson design (.37), and technology integration (effect size 1.43) compared to non-eMINTS control group teachers (Meyers et al., 2016). Average student achievement differences in mathematics were notable, with effect sizes of 0.13 (eMINTS) standard deviation units (Meyers et al., 2016). The program was implemented with 1,503 rural teachers and 15,036 students. These results meet the Strong Level of Effectiveness required for What Works Clearinghouse. eMINTS strategies combined with SGD curriculum provided the basis for oDREAMS PD, which proved demonstrated online PD approaches to be equally effective to blended or face-to-face models in supporting teacher implementation of CS curriculum and student outcomes (Repenning, 2015). Teachers have learned SGD through professional development (PD) and implemented it with students from third grade to college level, reaching more than 20,000 students across the U.S., including students in many diverse and underrepresented communities. SGD has been used in after school, summer enrichment, and in regular school schedule settings (NSF, 2018). The work proposed by eDGE will meet the



Zone of Proximal Flow (Fig. 2)

needs of all students in rural high-needs districts, provide opportunities for success with CS, and increase teacher and student exposure to and interest in STEM learning opportunities.

Potential of the Project to Increase Understanding of CS Education

The eDGE model promotes deeper learning. A key component of eMINTS is helping teachers learn to develop high-quality standards-based lessons to provide learning experiences that help students participate in complex, higher-order thinking tasks derived from the CCSS State Standards (CCSS) which evidence suggests is a challenge (Kane & Staiger, 2012). eMINTS encourages teachers to deepen students' thinking and to have high expectations for student work, an attitude especially critical in high poverty schools to prevent low expectations of ability (Welner & Weitzman, 2005). eMINTS training helps teachers learn to break down standards into knowledge, understandings, and skills that students must know, understand, and implement to successfully master a standard; develop formative assessments "for, as, and of" learning (Earl & Katz, 2006); and design authentic tasks to engage students. Our approach has been successful in a range of settings with a variety of local and state standards (Meyers & Brandt, 2010; Meyers et al., 2015). eMINTS earned the ***ISTE Mastery Seal of Alignment*** in 2013 (International Society of Technology in Education) and is prepared for the CCSS for technology integration and information literacy. eDGE will prepare teachers to incorporate these standards for students to use 21st century skills in authentic learning.

Issues: Instructional time, knowledgeable teachers, funding for resources, and efficacy are known obstacles for CS education in rural schools (Google Report, 2016) (Appendix I.3). ***First***, adding computer science (CS) to an overloaded curriculum is problematic and leaves schools using hit-or-miss approaches of before- or after-school clubs that tend to attract affluent and already connected students (Repenning, 2015). ***Secondly***, there is a lack of dedicated CS teachers, especially in rural schools, and a lack of time to add more to the existing curriculum (Shein, 2019). The lack of reliable assessments for CS education makes any impact of CS learning difficult to measure (Brookings, 2020). Core classroom teachers who are expected to meet these standards need a way to analyze results and measure achievement to justify the time for CS learning. ***Next***, there is a lack of funds for qualified teachers, for training teachers, and for purchasing equipment for CS education. The shortage of funds places the burden to meet CS standards on core teachers who lack knowledge and are short on time to implement CS education (Wangenheim, 2017). “Teacher training remains a challenge to develop the necessary skills and confidence levels for effective CS teaching and learning” (Brookings, 2020 pg. 4). Not only is the lack of funds for teachers an issue, but also the lack of funds for computers, which magnifies these issues in rural schools. ***Finally***, there is the issue of efficacy experienced in high poverty schools where educators sometimes practice the “soft bigotry of low expectations” (Welner & Weitzman, 2005). The same expectations pervade CS education with a stigma that CS and STEM require a “Geek Gene” (Brookings, 2020). Many rural and low-income areas are not meeting CS standards going into the crucial middle school grades where identities become more solidified and students with little exposure to technology and programming will become less likely to seek STEM careers (Google Report, 2016).

Strategies: The eDGE model is designed to overcome these issues by creating a seamless integration of CS and math for all students aligned to both CSTA and CCSS for School Mathematics (Logic Model, Appendix I.4). This approach of integrating STEM instruction teaches computer science in activities that include opportunities for mathematical inquiry so that student investigation of coding and CT is used to purposefully explore, test, and evaluate conjectures regarding mathematics. This motivates students for real and relevant uses of what they are learning in math (Webb, 2012). eDGE contributes curriculum enhancement for meeting CS 5th grade standards while offering overlapping standards at 4th and 6th grade levels. eDGE enhances STEM-identity for girls and underrepresented communities of learners, giving them the opportunity to use STEM skills for building games and simulations (NSF, 2018). Student pre and post surveys and interviews will assist in recognizing whether the eDGE model inspires students to seek more CS in STEM opportunities. Teachers in the study will complete two 6-week self-paced training courses (fall & spring), created and facilitated by eMINTS, to learn strategies following the eIM along with SGD using student-centered, guided discovery with AgentCubes Online (ACO) software (AgentSheets, Inc). These courses will prepare teachers to implement game design and simulation creation with students that integrate CS with STEM core content in upper elementary classrooms in Missouri.

Table 2. Contributions to Education Community
Our contribution to the educational community will be three-fold:
(1) eDGE will create a model for fidelity and flexibility to support CS education in a wide variety of rural contexts.
(2) eDGE will develop and validate a tool for measuring CT in student learning.
(3) eDGE will develop and measure effective practices for virtual PD and coaching support for CS education.

Adequacy of Resources and Quality of the Management Plan

The eDGE management plan is located in Appendix I.5. ***A full eDGE timeline is found in*** Appendix I.6. ***Year 1 of the eDGE model is a design-based implementation research***

methodology. Materials development begins January 2021 (Year 1) and continues throughout the grant project through an iterative process of feedback and revision to ensure the best possible materials for future implementations. This development and revision process will be the responsibility of eMINTS with input from our partner LEA, AgentSheets, Inc., and feedback from the pilot cohort and all subsequent cohorts participating in the eDGE project. ***This plan is a delayed treatment study design involving 47 schools, 94 teachers, and 1880 students*** (see Table 3).

Table 3. eDGE Timeline Overview

<table>
<tr><th colspan="2">YEAR 1</th><th colspan="2">YEAR 2</th><th colspan="2">YEAR 3</th><th colspan="2">YEAR 4</th><th colspan="2">YEAR 5</th></tr>
<tr><td>Jan 2021-
Sept 2021</td><td>Oct 2021-
Dec 2021</td><td>Jan 2022-
Sept 2022</td><td>Oct 2022-
Dec 2022</td><td>Jan 2023-
Sept 2023</td><td>Oct 2023-
Dec 2023</td><td>Jan 2024-
Sept 2024</td><td>Oct 2024-
Dec 2024</td><td>Jan 2025-
Feb 2025</td><td>Mar 2025-
Dec 2025</td></tr>
<tr><td colspan="3">Plan, Develop, Recruit</td><td colspan="2" rowspan="2">Treatment
Cohort A</td><td colspan="2" rowspan="2">Control
Cohort B</td><td colspan="2" rowspan="5">Efficacy Study Phase</td><td rowspan="5">Dissemination</td></tr>
<tr><td rowspan="4">Planning & Development</td><td colspan="2">Pilot Cohort</td></tr>
<tr><td>Game Design</td><td>Simulation Creation</td><td>Game Design</td><td>Simulation Creation</td><td>Game Design</td><td>Simulation Creation</td></tr>
<tr><td colspan="2">3 schools
6 teachers
120 students
(Prior Experience)</td><td colspan="2">22 schools
44 teachers
880 students
(Treatment)</td><td colspan="2">22 schools
44 teachers
880 students
(Control)</td></tr>
<tr><td colspan="2">Ongoing Iterative Design
(design, pilot, test, refine)</td><td colspan="4">Data Collection & Analysis
Schools Randomly Assigned to Cohorts</td></tr>
</table>

A pilot cohort will begin the eDGE Game Design (Course 1) in October 2021 (Year 1) and collaborate with eMINTS in the development and refinement of teacher materials. Upon completing Game Design, these two teams will collaborate in refining student materials while implementing game design with students by December 2021. This iterative process will continue in January 2022 (Year 2) with the pilot cohort completing the eDGE Simulation Creation (Course 2) and contributing to the refinement of teacher materials, followed by implementation of simulation creation with students by May 2022 and refinement of student and teacher materials by September 2022.

October 2022 (Year 2) teachers in Cohort A (treatment) will complete a pre-survey and begin Game Design. Upon course completion, Cohort A teachers will implement game design with students starting with a pre-survey and concluding with games created by December 2022. In January 2023 (Year 3), Cohort A will complete Simulation Creation and implement simulation creation with students, concluding by May 2023. Cohort A teachers and their students will complete post-surveys by May 2023, sharing insights into project implementation and feedback on possible revisions of materials. Interviews will be conducted with this cohort and their students to evaluate project perceptions, efficacy, and sustainability. All data collected will be analyzed to determine adjustments to training, materials, and coaching support. Cohort B (control) will continue with business as usual in Year 2, and the Pilot Cohort will be encouraged to continue working with students and contributing feedback for materials revision and efficacy study.

In Year 3, the pattern of teacher training, student learning, and materials revision will continue. This pattern of training and development focuses on fidelity with all groups training in similar time frames within relatively defined learning parameters. Cohort B will begin with a teacher pre-survey and Game Design in October 2023 (Year 3), implement game design with students starting with a pre-survey and concluding with games created by December 2023, move to Simulation Creation in January 2024 (Year 4), and implement simulation creation with students, concluding by May 2024. Cohort B teachers and students will take post-surveys and respond to interview questions by May 2024 to provide feedback for materials revision. Data collected from CTPA, surveys, and interviews will be analyzed to determine adjustments needed to training, materials, and support for learning. Pilot Cohort and Cohort A will be encouraged to continue working with students and contributing feedback on materials revision and the efficacy study.

Year 4 will be a viability study for continuation of the project. Pilot Cohort, Cohort A, and Cohort B will be encouraged to continue working with students and contributing feedback. All cohorts will be invited to continue using the ACO software with students through the end of Year 5. This provides an opportunity for more students to be impacted by the study than projected, with the potential for more than 3,500 students to experience CS in math and science core classrooms by the end of the eDGE project.

Year 5 begins the dissemination phase of the grant project. Once data from all cohort activities is analyzed, reports can be generated and evidence gathered to inform STEM education research in the design and implementation of activities that integrate CS into core classrooms. Scalability is an important proponent of this project. Offering online learning modalities for teacher PD and online access to software for teachers and students allows scaling to large numbers a plausible inception bearing examination.

Reasonableness of Cost

The eDGE model scales the SGD process in a blended classroom approach. This approach uses best practices of a face-to-face setting while delivering content and collegial sharing in an online environment. This PD model allows our experienced staff to train teachers anywhere in Missouri, reducing the costs of travel and other expenses associated with face-to-face PD. We piloted this model of PD in a previous NSF funded project called oDreams, gathering participant and staff feedback to inform revisions (NSF, 2018). Teachers are supported by virtual meetings facilitated with Zoom software, individual support calls, and with the use of video and cloud-based software to support virtual coaching sessions. While eMINTS has been using video and cloud software for virtual coaching sessions with promising results, best practices have not been formalized. ***The eDGE model will create and codify a virtual coaching cycle*** that alternates planning, goal setting, delivery, and reflection in a systematic fashion to promote facilitation skills (Center for Education Policy Research, 2015). Virtual coaching procedures are being developed by eMINTS and will provide a cost-effective means of providing ongoing support for teachers.

Remote teacher PD provides substantial cost savings, making technology an option and meeting required PD hours. Odden and Picus (2011) recommend an annualized investment of $955 per student per school year in PD, technology, and materials needed to change instructional practices and improve student performance. When adjusted for inflation to reflect the value of the dollar in 2020, the total recommended annualized investment for PD and technology increases to $1,090 per student per year. Estimated costs for the proposed project of [redacted] per student per year over five years for PD and technology are significantly below the total recommended by Odden and Picus (2011). ***Teachers will receive more PD hours than the mandatory requirement for effective teacher PD***, along with individualized instructional coaching (Vega, 2015). eDGE will encourage more students to seek STEM and CS courses and help more teachers feel empowered to teach CT. Expanding professional learning networks (PLN) for teachers will provide the additional support structure for this student-centered interdisciplinary inquiry philosophy (Ronfeldt, 2015). This online teacher community is a safe environment where teachers can ask questions, share their perceptions, and work collaboratively to create interdisciplinary projects with peers or support each other with remote or distance learning ideas (Garcia, 2019).

The eDGE model also provides PD for technology instruction in the classroom, an additional feature not included in many PD programs. With technology training, there comes a need for up-to-date equipment. Rural schools have faced challenges with access to equipment and connectivity that technology hub schools take for granted. eDGE will provide equipment, curricular resources, and software to help rural schools during the pandemic to increase connectivity if the potential for remote learning arises. Free access to the PD and software in the early phases will be gradually shifted to a pay model to expand and sustain the program when grant funding ends.

Key Personnel

Table 4. Key Personnel (Appendix B)	
Project Director	Carla Chaffin, eMINTS Educational Program Coordinator
Carla Chaffin is an innovative educator with over 12 years of experience in instructional coaching and educational program management. She is an expert working with educators to design and manage online and onsite PD programs. Carla was a classroom teacher implementing eMINTS with technology enriched lessons. As curriculum developer and trainer, she was instrumental in implementing the NSF supported oDreams project and subsequent Google grants related to coding in the classroom. She is highly adept at supporting schools in the implementation of STEM/STEAM initiatives across a variety of contexts including rural, urban, and suburban schools.	
Asst Projector Director	Lein Shory, eMINTS eLearning Director
Director with expertise in: training & professional development; project management; instruction; instructional design; online course design; learning management systems; content management systems; assessment; online & print graphic design and layout; writing and editing; and marketing & communications. Worked on oDreams project funded by NSF grant.	
CU Boulder Advisor	David Webb, Ph.D., Assoc. Professor of Math Ed
Dr. David Webb is Associate Professor of Mathematics Education and Affiliate Faculty in the Department of Mathematics at the University of Colorado Boulder. He is also the Executive Director of Freudenthal Institute US, an international research collaborative for mathematics education. His interests include teachers' formative assessment practices, curriculum development, and the design of professional development activities.	

<table>
<tr><td>SRI Team</td><td>Andrea Beesley and Carol Tate</td></tr>
<tr><td colspan="2">A leading non-profit education research firm with a staff of close to 200, SRI Education designs and executes large-scale, complex evaluations examining program implementation and impact using rigorous experimental and quasi-experimental methods. SRI currently leads over 20 RCTs across the country and is evaluating or has evaluated 15 grants at development, validation, and scale-up levels under the former Investing in Innovation (i3) program.</td></tr>
<tr><td>SGD Team</td><td>Nadia Repenning will lead the SGD team</td></tr>
<tr><td colspan="2">Repenning has extensive experience in and commitment to bringing educational end-user software environments and tools to K–12 national and international public, private, and charter schools as well as colleges and universities. She has managed several SBIR grants and awards and was responsible for meeting requirements for proposal submission, project reporting, and scheduling. She had sole responsibility for contract negotiation and FAR procurement compliance, and served as the primary administrative government contact.</td></tr>
<tr><td>LEA District</td><td>Karen Pfingsten, Affiliate Trainer at Southern Boone County Schools</td></tr>
<tr><td colspan="2">Southern Boone School District educates children from Ashland and the surrounding areas and has earned the state's Distinction in Performance Award annually since 2002. Serving roughly 1800 students. https://www.ashland.k12.mo.us/</td></tr>
</table>

Procedures for Ensuring Feedback and Continuous Improvement

eMINTS has a robust system in place of program feedback, evaluation, and iterative development (Meyers, 2016). eDGE will follow the same protocols found throughout eMINTS National Center projects. The management team will guide continuous feedback and improvement using an iterative design process. In the first nine months, our design team will collaborate with teachers in our partner LEA, Southern Boone County Schools, to develop PD experiences and materials. Then, we will field test the PD with our pilot schools. Formative data will be collected to inform project revision. This includes project records, teacher surveys, teacher and coach interviews, and classroom observations. The management team and all key personnel will meet monthly to evaluate data collected up to that time and determine what revisions are needed. This process will be repeated with our treatment and delayed treatment (control) cohorts. The process will ensure the materials provide a map of Computer Science, Math, and Science standards covered by each module of the eDGE model for students and teachers (Appendix I.8 Standards).

eDGE expansion demands that we meet the challenge of assessing student CT skills. The CTPA is a conceptualizing tool to measure CT skills and monitor program implementation locally to meet the unique needs of students and teachers in each school. The CTPA tool is integrated with classroom management systems, giving teachers a measure of student mastery of the CS principles in each project through automatically generated assessment reports (Webb, 2017). This tool also answers administrators' questions about how core teachers can evaluate student programming skills without a dedicated CS teacher (Vegas, 2020).

In Years 2-4 of the grant, external evaluators will conduct a randomized controlled trial of full implementation with 84 teachers from 42 schools. The treatment group (Cohort A) will receive eDGE intervention, whereas the control group (Cohort B) will not receive eDGE intervention until fall of Year 3 when data collection for Cohort A is complete. The same formative data will be collected from Cohort B as from Cohort A and will be reviewed monthly.

Dissemination

eMINTS research results and practices have been published in professional journals (Beglau, 2005), featured in a book chapter (Kaplan, Terry, & Beglau, 2014), and included in an ISTE white paper (Beglau et al., 2011). eMINTS is featured in practitioner journals such as Edutopia (George Lucas Foundation, 2012) and the Missouri STEM Coalition publication

(Chaffin & Terry, 2015). In January 2017, our Executive Director spoke at a White House higher education briefing on eMINTS as a sustainable model for PD. The eMINTS website will feature project milestones, results, and best practices along with annual reports. ***eMINTS, the University of Colorado Boulder, AgentSheets, Inc., and evaluators at SRI will create a dissemination team*** to collaboratively develop practitioner articles, practical guides, and white papers that help educators use the lessons learned from research in their classrooms. Research results from this project will be submitted to national professional and practitioner journals and regional and statewide publications. eDGE research results will produce a nationally disseminated 5th grade CS curriculum based on game and simulation design within core classrooms. The development of effective PD models will be available to a large national audience beyond the scope of eDGE, providing students with skills highly relevant to a 21st century workforce and motivating them to pursue future opportunities in STEM fields. We will choose one topic each year that highlights critical lessons learned with implications for the field of education. Together, we will present at research conferences such as the American Education Research Association (AERA) and practitioner-focused conferences such as the International Society for Technology in Education (ISTE). To build awareness of project resources and results, we are planning to partner with CSTA in offering conference sessions to attendees interested in implementing the SGD curriculum with their students. CSTA will also disseminate results directly to their extensive practitioner network through multiple media outlets. eDGE will create an annual report for project stakeholders that communicates project goals, progress, and outcomes. Reports will also feature success stories from schools that represent a variety of contexts across the project to be shared through our national network of LEAs and school districts. Resources for schools and

Outlook Partners will include materials for local conference presentations, recruitment packets, and social media templates for promoting project successes.

The @emintsnc Twitter handle and #emints hashtag are active and informative. eMINTS maintains a Facebook page and group, a LinkedIn site, and a Pinterest page. We use social media to promote our projects and disseminate grant findings. We maintain a Facebook page specifically for parents of students in eMINTS classrooms. Districts implementing eMINTS can easily share the materials on their own social media platforms for dissemination.

Quality of the Project Evaluation

SRI International will conduct a rigorous, independent evaluation of eDGE (see Table 5 for evaluation questions). The evaluation is designed to 1) produce evidence about the program's effectiveness that will meet What Works Clearinghouse standards without reservations, 2) articulate and measure eDGE's key components and establish thresholds for acceptable implementation, 3) use measures that will provide reliable and valid information about student outcomes, and 4) provide formative feedback on program usability and feasibility to project leaders. The impact study will be a cluster-randomized trial in which schools will be assigned to a treatment (eDGE) or control (business as usual) condition.

Table 5 Evaluation Questions, Data Sources, and Planned Analyses		
Questions	**Data Sources**	**Analyses**
1a: Does random assignment to eDGE significantly impact student motivation, engagement, and interest in computer science and STEM? 1b: Does random assignment to eDGE significantly impact student knowledge and application of computational thinking?	Student survey and computational thinking assessment	2-level hierarchical linear modeling

2a: To what extent is eDGE usable, feasible to implement with fidelity? 2b: What are eDGE's key components? 2c: What are the required thresholds for program adherence, exposure, delivery quality, and engagement? 2d: To what extent did eDGE meet the required implementation thresholds?	Review of eDGE materials Teacher questionnaire PD observations Teacher interviews	Qualitative analysis Descriptive statistics

Feasibility and Implementation Study (Q2). In Year 1, SRI will collect and share data on the usability and feasibility of eDGE during the continuous improvement cycles. Investigation of usability will focus on participants' experience of eDGE, while feasibility data collection will focus on whether eDGE can be implemented successfully in authentic education settings. SRI will virtually attend development meetings to observe the process and understand eDGE's components and intended use, as well as debrief with eMINTS developers. We will review eDGE materials, including PD presentations, for user-friendliness and readability. SRI will also interview the [teachers who are involved in design sessions] about their perceptions of the program and how the user experience could be improved. SRI will provide results and recommendations to developers monthly so that adjustments can be made on an ongoing basis.

During the 6-school study in Years 1 and 2, SRI will evaluate feasibility through a teacher implementation questionnaire, teacher interviews, and observations of virtual professional development activities. At this time, SRI will also work with eDGE developers to establish data-based thresholds for acceptable implementation in four key factors (Carroll et al., 2007): adherence (whether delivered as designed), dosage (how much was received), quality of delivery (whether delivered with intended techniques), and level of participant engagement. During the impact study, SRI will measure implementation fidelity against these thresholds and provide feedback monthly to eDGE developers. At the end of data collection, we will calculate a composite fidelity score. This will be a moderator of the outcomes in the impact analysis.

Implementation Measures, Data Collection, and Analysis. SRI will interview teacher participants using semi-structured interview protocols to learn about the perceived program effects on teachers' conceptions of computational thinking, student learning, and student motivation to engage in computer science. Teacher surveys will complement interviews as a way to gain insight into how teachers are integrating scalable game design activities into math and science classes, whether they are creating their own lessons incorporating eDGE, and whether they are adopting the eDGE instructional model. The focus will be on the extent to which eDGE can be successfully implemented in schools, how teachers and students react to it, and contextual features that seem to facilitate or hinder implementation. The PD observation protocol will focus on CS content, pedagogical approaches, and teacher engagement. Interview and observation data will be analyzed following a deductive and inductive process, beginning with a set of *a priori* codes covering aspects of teacher knowledge, background, and sense of preparedness to implement eDGE, and adding unanticipated codes that emerge from the data. Teacher survey data will be analyzed with descriptive statistics such as frequencies and means.

Impact Study (Q1). The 42 schools recruited in school year 2021-22 will be randomized to treatment and control conditions. In school year 2022-23, treatment schools will implement eDGE while control schools conduct business as usual. Primary impact findings will be calculated at the end of this school year. In school year 2023-24, the control schools will implement eDGE. This gives these schools an opportunity to take part in the program and serves as an incentive to remain in the study during the business-as-usual year.

A power analysis indicates that the school sample size is large enough to detect the assumed minimum detectable effect for this study of .20, based on literature on CS and math programs in 5th grade (e.g., Bush et al., 2020; Campuzano et al., 2009; Kelleher et al., 2007). SRI conducted power analyses using PowerUP! (Dong & Maynard, 2013), conservatively assuming 40 students in each school. SRI assumed an ICC of .10 (unconditional; Hedges & Hedberg, 2007) and a .70 proportion of post-intervention variance explained by a pretest score (Bloom, Richburg-Hayes, & Rebeck Black, 2007).

Impact Study Measures and Data Collection. To assess students' motivation, engagement, and interest in CS and STEM, SRI plans to administer the Student Motivation Survey (Bush, Gilmore, & Miller, 2020), which has been validated with fifth-grade students doing SGD. Exploratory factor analyses supported four dimensions: 1) general interest in CS, 2) future CS interest, 3) programming confidence, and 4) general CS confidence. Successful confirmatory factor analyses established the construct validity of these four dimensions as well as the internal consistency reliability of the dimensions and the overall scale. To assess computational thinking, SRI will leverage the Evidence Centered Design process (Mislevy & Haertel, 2006) to adapt a previously validated assessment, the Principled Assessment of Computational Thinking (PACT; Snow, Tate, Rutstein, & Bienkowski, 2017). The adapted CT assessment will be aligned to the CT learning targets in eDGE. SRI will administer the pre-survey and CT assessment to treatment and control schools before eDGE begins (school year 2022-23), and the post-survey and assessment when schools have completed eDGE.

Impact Study Data Analysis. SRI will conduct a two-level hierarchical learning modeling (HLM) model with students nested in schools (McGee et al., 2019; Raudenbush & Bryk, 2002). To increase precision, the Level 1 (student) model will include the pre-assessment scores. The Level 2 (school) model will include the indicator for group assignment, as well as school-level characteristics such as implementation composite score, average teacher experience, student body demographics, and level of participation in special education and free and reduced-price lunch. In addition, SRI will conduct mediator analyses to determine whether motivation, engagement, and interest in STEM and CS mediate the effects of eDGE on the CT assessment (Aivaloglou & Hermans, 2019; Guzdial et al., 2012; Witherspoon et al., 2017).

Attrition. Although attrition at the school level is expected to be small and similar across conditions, SRI will monitor school and student overall and differential attrition rates throughout the course of the study. If the achieved overall and differential attrition rates do not meet WWC standards, SRI will address missing data with non-response weights for missing outcome data (Hawkes & Plewis, 2006), and by incorporating indicators for schools missing covariate data into impact models.