Teacher Leader Engineering Network (TaLENt): A Collective Impact Model for K-12 Engineering Teacher Leaders (Work in Progress)

Christina Anlynette Crawford, Rice University

As Associate Director for Science and Engineering of the Rice Office of STEM Engagement, Christina leads the NanoEnvironmental Engineering for Teachers program. In this capacity, she guides Houston area secondary science teachers in weekly meetings on Rice's campus to "best practices" in educational pedagogy.

She currently has a B.S. in Biology from Texas A and M Corpus Christi, an M.S.Ed from the University of Houston, and is a Ph.D. student at the University of Houston studying Urban Education.

Carolyn Nichol PhD, Rice University

Dr. Carolyn Nichol is a Faculty Fellow in Chemistry and the Director of the Rice Office of STEM Engagement (R-STEM). R-STEM provides teacher professional development to elementary and secondary teachers in science and math content and pedagogy, while also providing STEM outreach to the Houston Community. Dr. Nichol's research interests are in science education and science policy. She received her B.S. in chemical engineering from the University of Massachusetts at Amherst, her doctorate in chemical engineering from the University of Texas (UT) at Austin, and served as a postdoctoral fellow in the College of Pharmacy at UT Austin. Prior to joining Rice University, she worked at Boehringer Ingelheim on innovative drug delivery systems and she was an Assistant Professor in Diagnostic Radiology at UT MD Anderson Cancer Center, where she conducted research on nonviral gene therapy systems. At Rice University she has developed and taught courses in The Department of Bioengineering including Numerical Methods, Pharmaceutical Engineering, Systems Physiology, Biomaterials and Advances in BioNanotechnology.

Dr. Robert Wimpelberg, All Kids Alliance, University of Houston

Dr. Robert (Bob) Wimpelberg is the Founder and Executive Director of All Kids Alliance at the University of Houston where he is Professor Emeritus and former Dean of the College of Education.

After 19 years in university administration and 50 years in education, Bob is dedicating his encore career to working with non-profits and funders interested in community-level collective impact. Through All Kids Alliance, Bob helps organizations pay particular attention to effective collaborative action and commitment to continuous quality improvement.

Bob graduated from Yale University and taught in public schools in St. Louis County, Missouri. Following doctoral work at the University of Chicago, he joined the faculty at Tulane University and later moved to the University of New Orleans. Bob has been at the University of Houston since 2000.

Bob was a founding member of the National Leadership Advisory Board of the StriveTogether Network during its affiliation with the KnowledgeWorks Foundation (Cincinnati). He is currently a Senior Fellow of the American Leadership Forum (Houston/Gulf Coast Chapter) and is serving on the Executive Committee of its Board of Trustees.

Dr. Jean S Larson, Arizona State University

Jean Larson, Ph.D., is the Educational Director for the NSF-funded Engineering Research Center for Biomediated and Bio-inspired Geotechnics (CBBG), and Assistant Research Professor in both the School of Sustainable Engineering and the Built Environment and the Division of Educational Leadership and Innovation at Arizona State University. She has a Ph.D. in Educational Technology, postgraduate training in Computer Systems Engineering, and many years of experience teaching and developing curriculum in various learning environments. She has taught technology integration and teacher training to undergraduate and graduate students at Arizona State University, students at the K-12 level locally and abroad, and various workshops and modules in business and industry. Dr. Larson is experienced in the application of

instructional design, delivery, evaluation, and specializes in eLearning technologies for training and development. Her research focuses on the efficient and effective transfer of knowledge and learning techniques, innovative and interdisciplinary collaboration, and strengthening the bridge between K-12 learning and higher education in terms of engineering content.

Dr. Alison Cook-Davis, Arizona State University

Dr. Alison Cook-Davis is Assistant Director for Program Evaluation at the Arizona State University's Office of Evaluation and Educational Effectiveness (UOEEE). She has a BA in Psychology, MS in Social Psychology, MLS Legal Studies, and a Ph.D. in Experimental Social Psychology. Prior to joining UOEEE, she supported the research and program evaluation efforts of Maricopa County Adult Probation Department, coordinated and executed the research and program evaluation for a large Department of Justice Second Chance Act grant. These efforts included monitoring, assessing, and evaluating the impacts of program outcomes. Since joining the UOEEE in 2015, Dr. Cook-Davis has led research and evaluation activities for over 50 separate grant-funded programs or initiatives funded by the National Science Foundation, U.S. Department of Education, U.S. Department of State, U.S. Department of Agriculture, National Institutes of Health, and The Kern Family Foundation. These projects have focused on the evaluation of student success, outreach impacts, innovative learning techniques, and STEM-related interventions and curricula.

Teacher Leader Engineering Network (TaLENt): A Collective Impact Model for K-12 Engineering Teacher Leaders (Work in Progress)

The Teacher Leader Engineering Network (TaLENt) is a working group of Teacher Fellows (TF's) with the overarching goal of increasing the number of Black, Native American, Hispanic, and female students pursuing Science, Technology, Engineering, and Math (STEM) degrees in college. The TaLENt project addresses this goal by engaging elementary, middle, and high school teachers from widely diverse backgrounds teaching in elementary, middle, and high school classrooms that are equally diverse. Divided into teams of five teachers of engineering for each school level, TF's are creating guidelines for quality engineering instruction. In turn, these guidelines are to be used by educators who want to incorporate engineering in their classrooms but have little experience with the field and minimal access to professional development [1]. While current support for such novice engineering teachers is often delivered in a "train-the-trainer" format using ready-made curricula, [2] TaLENt TF's are writing discrete sets of specific, measurable, achievable, relevant, and time-bound (SMART)[3] criteria that will facilitate K-12 curricula development of customizable school-level engineering resource. TaLENt aims to support a generation of underrepresented pre-collegiate students who are positive about STEM and conversant in the fundamentals of engineering.

In this work-in-progress paper, we review the current state of K-12 engineering education and contrast it with our approach to creating criteria for quality engineering instruction. We describe how our three working teams of engineering teachers were recruited and are going about the work of producing school-level specific SMART criteria. We highlight the role of collective impact practices in our methodology, and we outline some of the early outputs from our teams. The final deliverables will be available for use by K-12 engineering teachers across the United States, with specific distribution to National Science Foundation (NSF)-funded Engineering Research Centers (ERCs) that support Research Experiences for Teachers (RET) programs.

Current State of K-12 Engineering Education

Improving K-12 instruction in science and math has been a long-standing concern, while attention to K-12 instruction in engineering has lagged. The introduction of engineering education into K-12 classrooms has been exceedingly slow, and its development has been ad hoc[4]. A variety of curriculum projects for K-12 engineering emerged in the early 1990s without a national promoter for engineering education; it was up to local school districts to develop curricula, and, as a result, the products varied widely in their visions, goals, and formats [5]. Since the early 2000s, an assortment of K-12 engineering programs emerged, which span from in-the-classroom standards-based curriculum to after-school or independent programming [6]. Some generated curriculum and programs shared stand-alone lessons or units aligned to the Next Generation Science Standards[7], which provided a framework for engineering, but is still not adopted but all states. While other teaching materials focused on supporting the teacher's mindset. Described below are a few examples of K-12 engineering programs:

The Increasing Student Participation, Interest, and Recruitment in Engineering and Science (INSPIRES) Project is a set of five modules employing inquiry-based learning design for high school students. The INSPIRES curriculum focuses on integrating each of the four areas of STEM. INSPIRES aims to increase the number of women and other underrepresented groups in engineering. Provided to teachers is professional development for support before implementing the INSPIRES curriculum [8]. Project Lead the Way offers a curriculum designed for teachers to introduce high school students to engineering. Schools can purchase the program and follow prescribed curricular lessons and activities with 9-12 grade students [9]. The Infinity Project includes 3-6-week modules developed by engineering faculty and middle school teachers. To use the curriculum, schools must apply to become an Infinity Project school and complete a week-long professional development training [10]. Learning by Design is a set of individual units that use a project-based inquiry approach to teach science to middle school students. Real-world design challenges are provided for students to develop and present solutions to their teacher and peers[11]. TeachEngineering.org is an NSF-funded collaboration between five universities and the American Society for Engineering Education (ASEE). The TeachEngineering.org website offers a collection of K-12 engineering curricula aligned with standards that are free for teachers to download and use in their classrooms [12].

Engineering is Elementary (EiE) is a curriculum developed through the Museum of Science Boston for grades 1-5[13]. EiE has simplified the process of engineering design into a five-steps to provide early education engineering instructors and curriculum developers with an age-appropriate framework [14]. Curriculum developers and educational researchers, such as Kaya [15], have utilized the framework to introduce preservice elementary science teachers to engineering design.

Despite the expansion in assistance around engineering curricula and materials available to K-12 teachers, few of these resources are free of problems. Curriculum developers may not have a solid understanding of engineering concepts, or they may not know K-12 classrooms: how to present concepts to, say, elementary-age students or, in general, how to support student learning. According to [6], in addition to engineering design, teachers should include both the social and cultural importance of engineering to provide students with relevance. RET efforts and modules traditionally focus on delivering ready-made curriculum to K-12 teachers without providing teachers the freedom to adapt to the cultural needs and the diversity of their classrooms. Through the TaLENt program, we aim to create elementary, middle, & high school criteria that allow teachers to adapt engineering curriculum to the needs of their students or develop new materials without losing essential objectives of engineering.

The design of TaLENt Project is to provide just such a framework to help K-12 teachers develop and implement their curricula with high-quality engineering instruction. The TaLENt Project will not produce yet another engineering curriculum or set of classroom materials. Instead, TaLENt will create a guidebook of criteria central to engineering instruction, differentiated by school level: elementary, middle, and high school. They will anticipate authentic challenges and barriers that may arise in some classrooms, along with the tools and "workarounds" that can ensure success.

Participants

TaLENt leverages the NSF's RET programs to identify and recruit 15 K-12 teachers from across the US, and TaLENt drew its faculty and staff from two NSF-supported Engineering Research Centers (ERCs) (Rice University and Arizona State University). A program at University of Houston is providing project management support and practices associated with "collective impact."

The participant recruitment design targeted K-12 teachers who are STEM instructors in elementary, middle, and high school classrooms with experience teaching engineering in the classroom. The program received a total of applications Fifty-four total applications. Fifteen teachers were selected to participate in the program creating three teams of five teachers. Each team represents a different school level (elementary, middle, and high). A TaLENt faculty member facilitates each team. The selection process allows for as much racial, ethnic, gender, and geographical diversity as possible. Based on the selection process, K-12 participants were determined "experts in teaching" by meeting one or more of the following qualifications: 1) Possess a bachelor or master's degree in Engineering, 2) Teaches an engineering-specific course for at least two years, and 3) Demonstrated evidence of incorporating engineering design within their curriculum throughout the school year. Additionally, a RET program director letter of recommendation is collected. An outline of TF demographics is in Table 1 below.

Table 1. TaLENt Fellow Demographics and Location

Gender		Race		Ethnicity		Location	
Male	5	American Indian/Alaska Native	1	Hispanic or Latino	3	Arizona	3
Female	10	Asian	0	Not Hispanic or Latino	12	Georgia	1
Non-binary	0	Black or African American	6	Prefer not to provide	0	Mississippi	1
Prefer not to provide	0	White	7			North Carolina	1
		Prefer not to provide	1			Pennsylvania	1
						Texas	7
						Washington (State)	1

Processes

Working in three school-level teams of five teachers each, the TF held nine school-team webinars and came together for four whole-group webinars. All of the webinars lasted between 60 and 90 minutes. Three TaLENt faculty members served as facilitators for the team webinars and consulted with each other between webinars to check for cross-team understandings and pacing.

During the brainstorming phase, the TaLENt team faced challenges centered on student expectations, state and national standards, and culturally relevant approaches. TaLENt grade-level facilitators help guide teams through discussions that identified these differences. For example, the understanding of mixed representation and usage of engineering standards found with the Next Generation Science Standards[7] was essential to validate, as well as, each teacher's percentage of minority students in their classrooms. Each team grappled with identifying specificity level of criteria, ensuring that criteria reflected diversity and inclusion needs, ensuring indicators monitor learning actions and context, ensuring that indicators reflect learning that is meaningful and engaged, creating objectives that any subject matter teacher can use, and creating objectives beyond the steps of the engineering design process. The different perspectives continue throughout the creation of the grade-level criteria, indicators, barriers, and solutions.

The TaLENt project is to end in August of 2020. Table 2 below outlines the TaLENt 18-month project.

Table 2. Monthly Outline and Objective of Program

Month	Objective
Mar. 19	Whole Group - Setting the Stage
Apr. 19	Grade Level Meeting - session roles, team norms, expectations for homework & misconceptions in engineering
May 19	Grade Level Meeting - the goal of engineering in _ grade level, engineering in the classroom & preliminary criteria
Jun. 19	Whole Group - presentation of essential findings @ each grade-level introduction to the SMART framework
Jul. 19	Grade Level Meeting - refine criteria for specificity, clarity, diversity & redundancy
Aug. 19	Grade Level Meeting - developing data-driven indicators & criteria refinement
Sep. 19	Grade Level Meeting - developing data-driven indicators & criteria refinement
Oct. 19	Biennial ERC - Washington, D. C. Meeting
Nov. 19	Grade Level Meeting - developing data-driven indicators
Dec. 20	Grade Level Meeting - refining the Indicators and preparing for the presentation
Jan. 20	Whole Group - presentation of indicators & timeline of completion
Feb. 20	Grade Level Meeting - corrections based on feedback
Mar. 20	Grade Level Meeting - a discussion of barriers & solutions suggested by peers & edits needed
Apr. 20	Grade Level Meeting - draft grade-level report
May 20	Whole Group Presentation – grade-level report
Jun. 20	Final Report Due
Jul –Aug 20	Leadership team consolidation of language

Role of Collective Impact

In planning and conducting all webinars and the Washington work session - whether for the project management team or the Teacher School-Level Teams – practices associated with collective impact are central. First, methods of "results-based facilitation" guide all meetings to move talk to action. Second, TaLENt school-level team webinars engage all Fellows by assigning specific roles (Note Taker, Time Keeper, Meeting Summarizer, Reporter, or Participant) to Fellows. Every meeting ends with action commitments. Third, the work process in the school-level teams respects multiple perspectives in search of a common goal.

Furthermore, measurement is a constant, whether applied to meet "outputs" or project "outcomes." The culminating product – a guidebook of criteria for designing high-quality engineering instruction in elementary, middle, and high schools – will represent the application of all of these collective impact practices. The guidebook will adapt the concept of SMART goals to describe instructional criteria that are Specific, Measurable, Achievable, Relevant, and Time-bound.

Preliminary Results

After an initial session on "What does engineering look like in the classroom," fellows brainstormed critical practices in the classroom, and themes emerged. A discussion on themes became the basis for the SMART criteria for elementary, middle, and high school classrooms. The criteria are developed separately by each of the teams. However, each team worked toward the common goals of developing processes and practices that would be beneficial to share with teachers and prepare diverse students for more in-depth learning at each school level.

Each TaLENt team defined what engineering instruction should look like at their particular school-level. TFs bring to the project their experience as engineering teachers who know the building-blocks of engineering as well as the age-centric capacities and interests of the students with whom they are working. The TaLENt elementary grades team is introducing engineering design concepts into a learning environment conducive to cooperative problem-solving. The instructional criteria from this team are gravitating toward the support of risk-taking, open communication, collaboration, and brainstorming skills. The TaLENt middle-school team is building on this foundation by delving more deeply into engineering practices of design. Initial criteria from this team emphasize hands-on opportunities and scope the full engineering process, including evaluating and iterating design solutions. The middle-school team is also proposing that pre- and young teens can learn how to ask questions, undertake research, develop plans, and do team prototyping. At the high-school level, criteria for high-quality instruction are precursors to collegiate-level engineering. The high school team focused on aspects of engineering skills that prepare students for college-level courses. Some examples of these skills include the ability to analyze real-world problems critically; identify and define problems with increasing complexity; utilize appropriate tools; analyze data to integrate multiple disciplines to solve a problem; conduct practical research to understand both social and environmental impacts of design, and collaborate within specific team roles.

Each school-level criterion developed includes a set of indicators, barriers for implementation of the criteria, and realistic strategies for overcoming these barriers. To work through some of these barriers, teachers tried out techniques and practices in their classrooms to test them informally. The educators are continuing the process by gathering data from other teachers to help identify barriers and solutions for the implementation of the developed criteria and indicators. As each school has students with different baselines, teachers need to respond to the unique makeup of that population culturally. In order to do this, a school representative collects the baseline data. Developed indicators will include strategic wording that allows the instructor or school representative to understand data collection checkpoints to determine progress towards the criteria. Table 4 highlights an example set of criteria and indicators developed by TaLENt Fellows at each school level.

TABLE 3. Examples of criterion and indicators developed for teaching engineering at each school-level

School Level	Criteria	Indicator(s)*
Elementary	The teacher develops a student-driven environment through argument strategies stressing the importance of cooperative problem-solving.	● Percentage of students using the argument strategies taught in class increases by XX% after six weeks, 12 weeks, etc... compared to the beginning of the year (BOY). ● Percentage of students who can cooperatively solve the posed problem increases by XX% compared to the BOY.
Middle School	Based on learning preferences, the teacher will facilitate the gathering of ideas by modeling the brainstorming process, specifying a minimum number of ideas, evaluating the relevance of those ideas, and providing accommodating feedback to teams of students. Idea generation will prepare students for the next phase of the engineering design cycle.	● The number of valid resources used to gather ideas (web sites) increases by XX% compared to the BOY. ● The number of relevant ideas used (mind map, outline
High School	The teacher will facilitate classroom activities that account for the social and environmental impacts of design solutions and expose students to a variety of social and environmental issues to build background knowledge for students to evaluate and communicate potential impacts for their design.	● The ratio of student-generated vs. teacher-generated potential consequences compared to the BOY. ● Percent of positive and percent negative impacts discussed by students at the end of the project. ● Percent of students who include environmental and social impacts in their problem statement compared to BOY.

**XX represents a placeholder for teacher-derived percentages, which allows each instructor flexibility in deciding appropriate goals of growth based upon the classroom demographics and needs.*

Future Work

Evaluation of the drafted TaLENt guidebook will occur by a series of professionals familiar with engineering practice and engineering education. The current plan is to present the results of the program at the next meeting of the NSF Engineering Education and Centers (EEC) grantees meeting, as the leaders on this project have an NSF Research Experience Site program (EEC-144950). Additionally, we also plan to present our results at the NSF ERC Biennial meeting; this is relevant since multiple ERCs are participating in this project, and most of the TaLENt teachers are RET interns. Finally, we will vet the TaLENt guidebook through the ERC

Education Leaders' monthly calls and with undergraduate engineering faculty and industry members.

Because the TaLENt guidebook for high-quality engineering instruction is being created by practicing classroom teachers as a support for other teachers wishing to design engineering learning activities, the most critical review panel will be K-12 "end-users" themselves. To reach this audience, we plan to disseminate this guidebook to teachers participating in RET programs across the country. ERC leaders and RET program directors will receive finalized TaLENt criteria. It is our goal to collect feedback on how the criteria assisted in the development of engineering lessons and the level of incorporation within the RET programs.

Our systematic process of vetting the TaLENt guidebook will allow us to study how teachers are using it and with what levels of effectiveness. For that research, we will seek additional funding to study how teachers use and apply these materials.

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