



Evaluation of Research Experience or Teachers (RET) Program Effectiveness as STEM Professional Development

Mrs. Katie Estridge Schneider, Colorado School of Mines

Katie Schneider is graduate student studying hydrology at Colorado School of Mines (CSM). Prior to grad school, Katie taught high school science and math in the North Carolina public school system. As she works towards a master's degree in hydrology, she also serves as the Education Outreach Assistant for the Center for a Sustainable WE2ST, at CSM.

Amy Charlotte Martin P.E., Colorado School of Mines

Dr. Terri S. Hogue, Colorado School of Mines

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Abstract

The Colorado School of Mines (CSM) hosts a National Science Foundation funded Research Experience for Teachers (RET) program that focuses on STEM content surrounding the water-energy nexus (WE²NG: Water-Energy Nexus for the Next Generation). The objectives of this program are to: 1) impact teacher participants by increasing their knowledge of the water-energy nexus and by expanding their perspectives on science, engineering and research, 2) to indirectly impact K-12 student's learning, motivation and engagement by increasing teacher passion and awareness and by providing mentors for CSM in the K-12 classroom, and 3) to impact K-12 STEM curricula via the creation of standards-based active learning lessons infused with current research which will be available through local, regional and national forums. During the summer of 2017, we systematically evaluated the effectiveness of the WE²NG RET program through pre-program, post-program and weekly surveys, employing both quantitative and qualitative questions. By measuring teacher satisfaction/agreement (%) with respect to the following categories, post-program quantitative responses indicated high levels of program effectiveness; as a professional development program (94.4%), mentor relationships (88.9%), types of learning experiences (88.9%), program accomplishments (83.4%), personal impact (91.4%) and overall experience (92.3%). Quantitative responses from weekly program surveys show increasing levels of program satisfaction (in seven of eight categories) throughout the duration of the RET program. Ongoing work includes evaluation of qualitative survey responses to further measure program effectiveness and to assess self-efficacy in teacher participants. Results will help formulate the remaining summer WE²NG programs as well as future K-12 outreach at the Colorado School of Mines.

I. Introduction

Research Experience for Teachers Overview

The Research Experience for Teachers (RET) program is a National Science Foundation (NSF) funded summer research opportunity that is hosted at various post-secondary research institutions in the United States. The RET program serves to support collaborative partnerships between K-12 and community college Science, Technology, Engineering and Mathematics (STEM) teachers and post-secondary research faculty and students. Through these long-term partnerships, the goal of the RET program is to enhance STEM content knowledge in teacher participants through their exposure-to and immersion-in a summer research experience hosted by a research university. The program is also designed to support the translation of the research experience learning outcomes into meaningful curriculum development for K-12 and community college teacher participants. Following summer participation in the RET program, research teams (university research faculty and students) continue to support teacher participants in future academic year(s) through classroom visits, collaborative curriculum development and/or in other ways that meet the unique needs to each teacher.¹

In 2016 the National Academy of Sciences published *Science Teacher's Learning*; reviewing literature on professional development for science teachers.² They report that most high school teachers hold a science degree, but less than half of middle school teachers, and only five percent of elementary teachers have the same. Thus, it seems unlikely that that primary and middle-grade teachers have sufficient exposure to STEM disciplines to effectively deliver STEM curriculum (especially as STEM standards become more rigorous). The same publication concludes with recommendations for ways to enhance content knowledge in science educators.

Recommendations most relevant to this study include; increasing science content learning opportunities (especially specialized learning opportunities both in and out of the school setting), the development of partnerships between K12 educators, industry and institutions of higher education and the introduction of science specialists at the primary level through outside sources or internal vertical collaboration. The authors of the present study believe that RET programs, and especially the model described here, clearly and effectively address each of these recommendations. Further, RET programs have been shown to improve science teachers' confidence in content knowledge and in connecting applied science to classroom practices.³ Teacher confidence plays an important role in both teacher and student performance.^{4,5}

WE²NG Program

The Colorado School of Mines (CSM) hosts a summer RET program that is open to local public K-12 STEM teacher. The CSM RET site, Water-Energy Education for the Next Generation (WE²NG). As of the date of this publication, the CSM RET site, *Water-Energy Education for the Next Generation* (WE²NG) has been operational for two years and focuses on the water-energy nexus. Water and energy sciences are highly interdisciplinary with applications to STEM curriculum of all grade-levels. Long-standing relationships with industry partners, in conjunction with ongoing cutting-edge water-energy research makes CSM a unique RET host-university with the capacity to connect researchers, K-12 teachers and industries.

The WE²NG program consists of a six-to-eight week full-time summer research experience at CSM, where teacher participants are paired with a research group (faculty research advisor and research students who work under them), who’s research aligns most-closely with the curriculum taught by the participant. Each summer training allows up to 10 new teachers per cohort. During the second summer training (2017), teachers from the first cohort (2016) were invited to return on a part-time basis (allowing up to five total), where they served as mentors to new teachers. Inclusion of teachers ranging from primary to secondary, in a localized geographic area, creates an environment that encourages both horizontal and vertical curriculum alignment. By the end of the summer program, participants are expected to produce a final deliverable for their classrooms, which may take the form of a lesson or unit-plan, which infuses knowledge gained from their research experience into their classroom practice.

WE²NG summer trainings have three distinct “phases” – starting with an orientation week (typically a half-week), followed by four-to-five full weeks focusing on research and curriculum and development, and concluding with a week that consists of a “Showcase of Lessons” (a presentation of the final deliverable) and extended field trip. The orientation week consists of a campus tour, explanation of program expectations, final deliverable demonstrations by master teachers, a laboratory and environmental health and safety presentation and initial faculty research group meetings. The weeks following orientation are full of activities (Figure 1) aimed at K-12 STEM professional development, including; workshops, book-club discussions, graduate student research presentations, collaborative meetings, industry field trips and, of course, hands-on research experience within a faculty-advised research group. These weeks contain the most learning-opportunities, and although they are activity-dense, WE²NG summer trainings are believed to be of sufficient duration to allow participants to meaningfully engage with their research assignment and to ultimately take ownership of their role within the research team.

WE ² NG Program Weekly Structure				
Monday	Tuesday	Wednesday	Thursday	Friday
Workshops focused on water and energy curriculum specific to K-12 grades (all day)	Research within faculty research group (all day)	<u>Morning</u> Research within faculty group	Research within faculty research group (all day)	Industry field trips related to water and energy production and/or challenges in Colorado (all day)
		<u>Afternoon</u> - Graduate student research presentations over lunch - Teacher-lead book club discussion (covering water and energy texts ranging in technicality) - Collaborative meetings with master teachers to support vertical and horizontal curriculum alignment		

Figure 1 – Weekly WE²NG Program Structure

During the final week of each WE²NG summer training, participants present their final deliverable to WE²NG stakeholders and local school district personnel at the Showcase of Lessons. Following the showcase, the program concludes with an extended (two night) field trip to an area within Colorado that employs unique water-management solutions to industrial,

agricultural and municipal water practices (Figure 2). Through a variety of industry tours, research-site visits and meetings with local water-energy stakeholders, the extended field trip provides ample opportunities for participants to revisit and apply knowledge they learned in the previous weeks.

WE²NG Program Objectives & Goals

The WE²NG program seeks to infuse current water-energy research into K-12 classrooms through collaborative partnerships between CSM researchers and local K-12 STEM teachers. The specific program objectives are to: *1) impact teacher participants by increasing their knowledge of the water-energy nexus and by expanding their perspectives on science, engineering, and research, 2) indirectly impact K-12 students' learning, motivation, and engagement by increasing teacher passion and awareness and by providing mentors from CSM in the K-12 classroom and 3) to impact K-12 STEM curricula via the creation of standards-based active learning lessons infused with current research which will be available through local, regional, national, and global forums.*



Figure 2 – Photos from the 2017 WE²NG Extended Field Trip.

Left: Jamie Hart's commercial potato farm (San Luis Valley, CO).

Right: Summitville mine superfund site (Rio Grande County, CO).

II. Methods

To evaluate the effectiveness of the WE²NG model as a means of STEM professional development, pre-program, weekly and post-program surveys were administered to participants. To encourage un-biased feedback, participants were randomly assigned numerical-identifiers that were kept confidential to survey-evaluators. The numerical identifier served to keep participant feedback anonymous, while identifying the cohort of the participant. All survey questions were approved by an external program evaluator (per NSF requirements) before they were administered using the free Google Forms product. The pre-program surveys were completed prior to WE²NG orientation, weekly surveys were completed at the end of each week, and, to allow time for reflection, post-program surveys were completed within two weeks after the program-end. For purposes of consistency, master teachers did not participate in these surveys.

Surveys included both qualitative (written, non-numerical) and quantitative (raked, numerical) responses. The results presented in this study only consider numerical responses presented as average responses, representing the arithmetic average response from all participants for a given question. Weekly surveys are presented as average responses to individual questions re-evaluated each week, to determine feedback change with time. For brevity, post-program surveys are summarized in groups of questions (rather than individual questions), where results represent the average response for all of the questions within a group of questions. Since post-survey questions were not all ranked on the same numerical scale, responses were normalized by converting responses to percentages before averaging. Pre-program survey results are not presented, as they are not (currently) relevant to the program evaluation. Beyond averaging, additional statistical analysis was not performed because the sample size (nine participants in 2017), does not meet the minimum size requirement of the Central Limit Theorem.

III. Results & Discussion

The WE²NG program has completed two summer training sessions (2016 and 2017), however, presented herein are specific to the 2017 WE²NG program. It should also be noted that surveys (especially pre- and post-program surveys) were lengthy, and not all questions in the surveys are relevant to this work, thus only the most relevant survey results are presented in this report.

Weekly Survey Results

Weekly surveys, given for all six weeks of the 2017 WE²NG program, including the first and last weeks, were the same each week (with the exception of two questions that were unintentionally left out of the Week 1 survey). This allowed for an evaluation of various program aspects over time and provided valuable insight about specific program activities. Relevant weekly survey results are summarized in Figure 3, below. Trend lines are included in the weekly plots to show the general trend in participant agreement/satisfaction for each category. In seven of eight total categories feedback shows progressive improvements in participant satisfaction/agreement. These results are encouraging, and generally consistent with the expectation that collaboration will develop and improve over the course of the program.

In the ‘plan and format of weekly activities’ category, participants tended to become less satisfied across the duration of the program. Even though this negative trend is slight, and on average satisfaction is high (>85%), this result suggests that a modification in the order and/or type of weekly activities could improve participant satisfaction. From these results, other constructively critical conclusions can be drawn: expectations with in faculty research groups need clarification toward the beginning of the program, the amount of time spent on each activity could benefit from modification, certain book-club discussions were received better than others, and practical collaboration and curriculum development needs improvement near the beginning of the program.

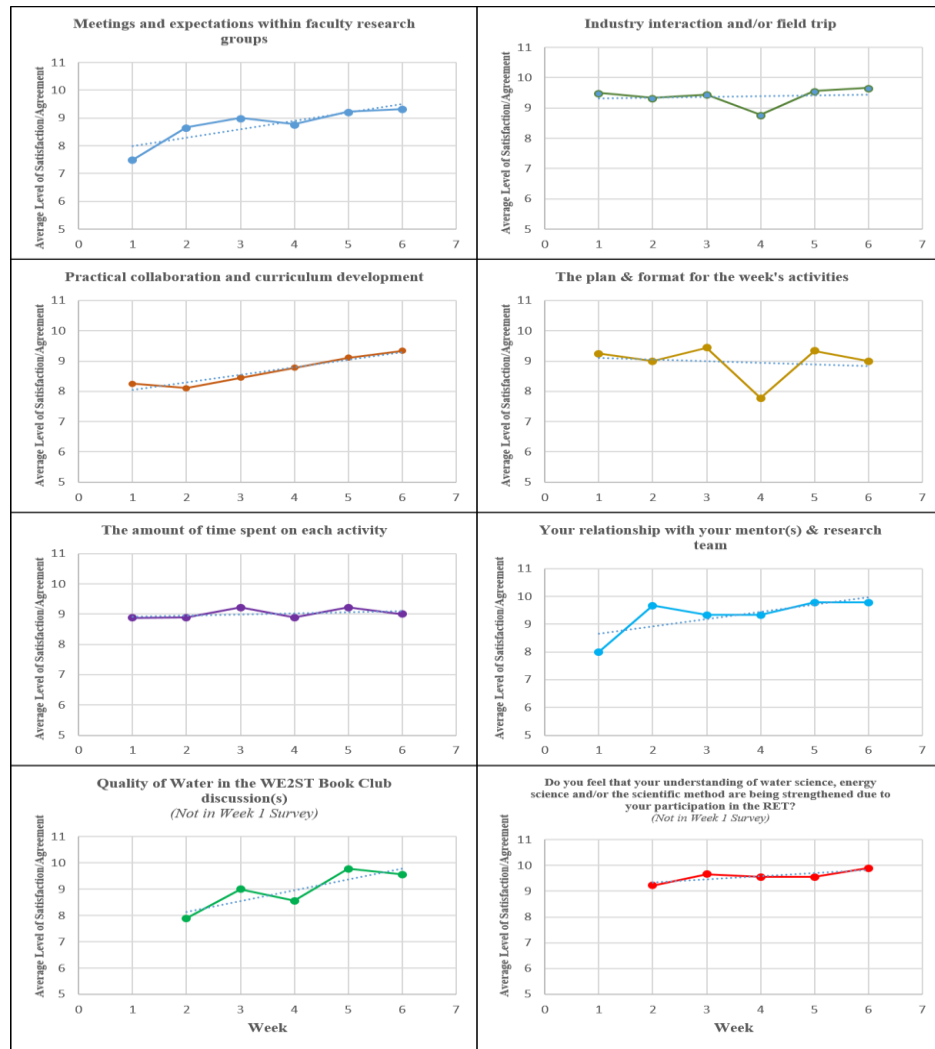


Figure 3: Summary of Weekly Survey Results

Post-program Results

As noted above the post-program survey was lengthy, so for this analysis, relevant survey questions were sorted into groups which include the following categories: overall experience, personal impact, program accomplishments, types of learning, WE²NG as a professional development program (only one question in this “group”) and mentor relationships. Specific questions asked in each group are located in the appendix of this report. Average participant responses for each group of questions are summarized in Figure 4, below. In Figure 4, error bars represent the average standard deviation of responses within each group of questions, and are shown to illustrate the relative spread of responses (not to imply that any degree of quantitative error is associated survey results). For each group of post-survey questions, average participant satisfaction exceeds 80%, indicating highly positive feedback overall. The area with the greatest room for improvement is ‘program accomplishments’, although participants had relatively inconstant agreement with respect to this area (as indicated by error bars). Another notable result from this analysis is that, as a professional development program, participants gave the WE²NG

program its highest ranking. This is especially significant because, relative to other categories, participants agreed the most in this area.

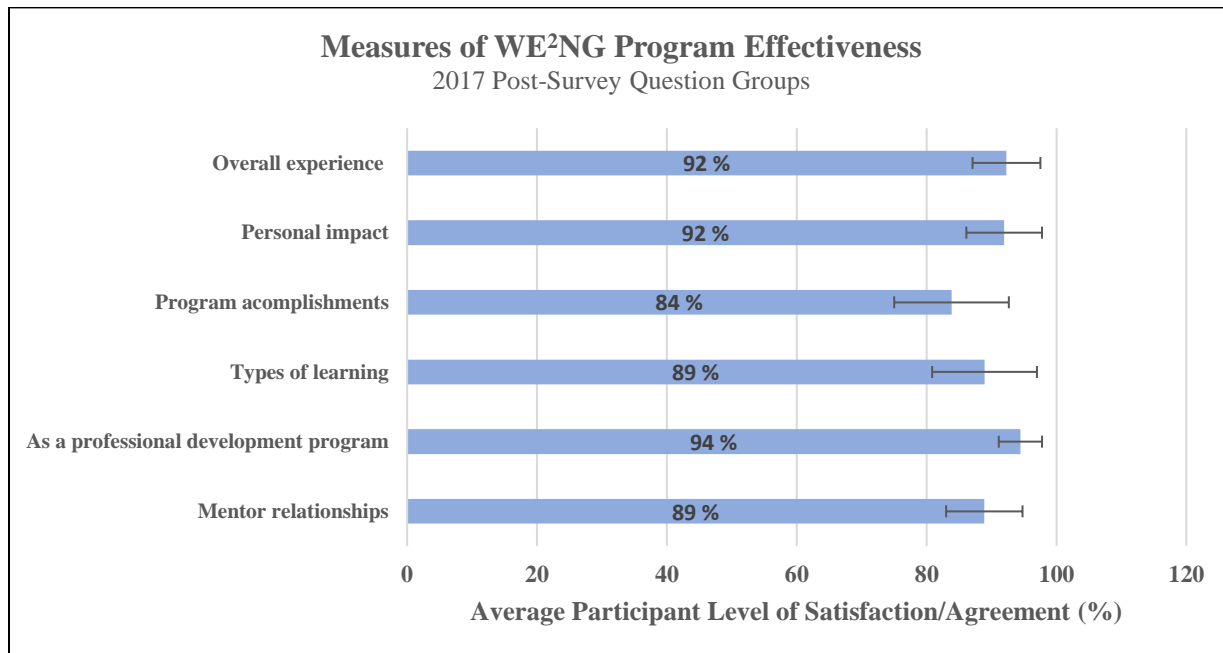


Figure 4: Measures of WE²NG Program Effectiveness by Post-Program Question Groups

Ongoing Work

The results presented above will inform the structure of future WE²NG RET programs, with the goal of improving all areas with room for improvement, and especially those with the greatest room for growth. To improve the assessment of the WE²NG program, the following areas are currently being explored for implementation in future surveys:

- Modification of pre- and post-surveys to evaluate the same criteria before and after the program. Like current weekly surveys, evaluating responses in this way will allow for greater analysis of participant growth. The authors are especially interested in studying how participants feel that their STEM content knowledge, ability to communicate science, and self-efficacy as STEM teachers improves (or otherwise) as a result of WE²NG program participation. Due to external evaluator oversight of existing surveys, this may require generation of new surveys (in addition to the current surveys required by external evaluators), or if allowable, modification of existing surveys.
- Surveys created specifically for master teachers, to assess the value of their experience as mentors to new teachers.
- Implementation of “codebooking” to quantitatively assess qualitative survey responses (written, non-numeric answers). Currently, qualitative survey responses are recorded and considered in the planning of future WE²NG structure. However, due to the quantity of feedback presenting these data in a concise and comparative manner is currently not possible without standardizing and distilling qualitative responses into a more manageable form.

IV. Conclusions

The Colorado School of Mines WE²NG RET program has proven to be a highly effective professional development model for K-12 STEM teachers. During the 2017 summer training, participant feedback gathered via Google Surveys indicated overall positive responses with respect to overall experience, personal impact, program accomplishments, exposure to various learning types, mentor relationships and quality of professional development. Weekly surveys show growth in seven (of eight) categories of participant satisfaction; especially in areas relating to communication. These surveys have also been used to identify areas with room for improvement within the WE²NG program, and are currently being used to inform the structure of the 2018 summer training program. To improve the program evaluation process, future surveys will be modified to measure participant growth in key areas of interest, surveys will be generated specifically for master teachers, and codebooking is being explored as a mechanism to analyze qualitative survey responses.

V. Acknowledgements

The authors would like to thank the National Science Foundation for providing funding for the WE²NG RET summer training, a program that has directly benefited many K-12 STEM teachers, university research faculty and students, and has indirectly benefitted an even larger number of K-12 students. Further, the WE²NG program would not be possible without CSM research faculty and students who, through sacrifices in time, energy and resources, provide invaluable guidance to WE²NG teacher participants. Lastly, the authors would like to thank all of the K-12 teachers who have enthusiastically forgone their summer break to improve their capacity as STEM teachers by participation in the WE²NG program.

VI. References

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VII. Appendix

Summary of Post-Survey Questions by Group

Group 1: Overall Experience

General Participant Satisfaction with the WE²NG RET Program

Please indicate your level of satisfaction with your experience in each of the following areas:

- *The materials and information you received before you began the RET experience*
- *The orientation you received when you began the RET experience*
- *The expertise and helpfulness of your mentor(s) in answering questions and problem solving*
- *Your relationship with your mentor(s)*
- *The opportunity to participate as a member of a vertical team*
- *The opportunity to ask questions of the staff/scientists in the mentor's lab*
- *The opportunity to intersect and discuss issues with other members of the RET team*
- *The availability and quality of resources, materials and equipment*

Program Level of Fit to each Participant

To what extent, if any, was your RET experience successful in each of the following areas:

- *It was responsive to your professional development needs*
- *It was appropriate to your knowledge, skills and interests*
- *It provided the opportunities to engage in inquiry/research activities that you will be able to adapt for classroom use*
- *The research assignments were clearly defined*
- *The work was enjoyable and stimulating*
- *The scope of the project was appropriate for the time you were on site*

Group 2: Personal Impact of the RET Program

To what extent do you agree or disagree with each of the following statements concerning the impact of the experience on you personally?

- *It increased my confidence in myself as a teacher*
- *It elevated my enthusiasm for teaching*
- *It increased my interest in research and the ways that science mathematics, or technology can be applied*
- *It stimulated me to think about ways I can improve my teaching*
- *I believe I will be a more effective teacher*
- *It increased my interest and ability in networking with teachers and other professionals*
- *It increased my motivation to seek out other experimental professional development activities*
- *It increased my commitment to learning and seeking new ideas on my own*

Group 3: Program Accomplishments

To what extent do you feel you accomplished the following during your research experience?

- *Developed insight into the process of scientific research*
- *Developed an appreciation of the daily work of a scientific researcher*
- *Contributed to your mentor's research project*

- *Improved your skills*
- *Accepted constructive criticism in a professional manner*
- *Adjusted to the challenges of the laboratory environment*
- *Shared with your mentor ways in which you might use your research experience in the classroom*
- *Communicated with your mentor that this program is worthwhile for you and other teachers*

Group 4: Types of Learning as a Result of the WE²NG Program

To what extent, if any, did you feel that you experienced each of the following types of learning as a result of your summer experience?

- *I gained greater understanding of the applications of science, mathematics, or technology in everyday life.*
- *I acquired greater understanding of the fundamental concepts in science or mathematics*
- *I became more familiar with new materials and equipment that I can use in my teaching*
- *I learned about innovative ways to use standard materials and equipment in my field*
- *I increased my knowledge of current issues in scientific or mathematical research*
- *I gained a greater appreciation of the difficulties some students encounter when learning science or mathematics*
- *I better understood how collaborative inquiry can be done successfully*
- *I learned about magazines, professional journals and websites that will be relevant to me as a teacher*
- *I increased my knowledge of careers that utilize science, mathematics, and/or technology*

Group 5: WE²NG as a Professional Development Program

- *As a professional development program for teachers, how would you rate the RET program?*

Group 6: Participant Response to Mentorship

Please rate the extent to which your mentor(s) met your expectations in each of the following areas:

- *Your mentor's preparation for your arrival*
- *Your mentor's knowledge and support of the goals of the RET program*
- *Your mentor's knowledge of the roles and responsibilities of teachers in your field*
- *Your mentor's interest in helping you develop a plan to improve education in science, mathematics and/or technology*
- *Your mentor's commitment to providing opportunities for you to learn and gain expertise in new areas*
- *Your mentor's ability to communicate information and expectations clearly*