An Interdisciplinary RET Program: Assessment with Concerns-Based Adoption Model (RTP)

Jeremy Dylan Smith M.S., Virginia Tech

An Engineering Education doctoral candidate at Virginia Tech, Jeremy has both a bachelors and masters degree in mechanical engineering from The University of Oklahoma. He was heavily involved in extracurricular activities there including SAE Baja, Pi Tau Sigma, and other clubs. Through these numerous experiences, he learned to appreciate different ways of learning and knowing, and decided to pursue a philosophy degree in the education of engineering content.

Dr. Vinod K. Lohani, Virginia Tech

Dr. Vinod K. Lohani is a Professor of Engineering Education and also serves as the Director of education and global initiatives at an interdisciplinary research institute called the Institute for Critical Technology and Applied Science (ICTAS) at Virginia Tech. He is the founding director of an interdisciplinary lab called Learning Enhanced Watershed Assessment System (LEWAS) at VT. He received a Ph.D. in civil engineering from VT. His research interests are in the areas of computer-supported research and learning systems, hydrology, engineering education, and international collaboration. He has served as a PI or co-PI on 16 projects, funded by the National Science Foundation, with a $6.4 million research funding participation from external sources. He has been directing/co-directing an NSF/Research Experiences for Undergraduates (REU) Site on interdisciplinary water sciences and engineering at VT since 2007. This site has 95 alumni to date. He also leads an NSF/Research Experiences for Teachers (RET) site on interdisciplinary water research and have 10 alumni. He also leads an NSF-funded cybersecurity education project and serves as a co-PI on two International Research Experiences for Students (IRES) projects funded by the NSF. He has published over 90 papers in peer-reviewed journals and conferences.
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J.D. Smith and V.K. Lohani
smithjer@vt.edu, vlohani@vt.edu
Department of Engineering Education
Virginia Tech

Abstract
In 2008, the US National Academy of Engineering (NAE) announced fourteen Grand Challenges in engineering that require solutions in the 21st century. A Research Experiences for Teachers (RET) site at Virginia Tech (VT) is motivated by this Grand Challenge and aims to educate local teachers (and through them their students) about the interdisciplinary aspects of water research to make them aware of water-related issues, and to guide them to develop appropriate solutions to address these challenges. In this work we share details of our RET site and our assessment findings for the first two years of the RET program regarding teacher concerns for adoption of innovative curricular material and their levels of implementation of the activities in their classrooms. We conducted a small survey, focus group, and utilized two instruments from the Concerns-Based Adoption Model (CBAM): the Stages of Concern questionnaire (SoC) and Levels of Use (LoU) interviews, on the first two cohorts of our RET program. Eleven of the teachers thirteen teachers interviewed have implemented in their classes at least once. We did not find a generalizable correlation between creative achievement and level of implementation, but the teacher with the highest creative achievement questionnaire (CAQ) score implemented three projects within the semester immediately following the summer professional development program. The focus group revealed teachers had enthusiasm and gratitude for the summer program overall.

Keywords: professional development, Research Experiences for Teachers (RET), innovation adoption, interdisciplinarity, water, RET, CBAM, curricular design

Introduction
In this paper we share our experience with the first two years of an interdisciplinary water Research Experiences for Teachers (RET) program at VT. The RET site was made possible after the faculty mentors successfully implemented a Research Experiences for Undergraduates (REU) program for ten years [1,2,3]. In 2008, the US National Academy of Engineering (NAE) announced 14 Grand Challenges in engineering that require solutions in the 21st century. This list includes the challenge to “provide access to clean water” [4]. This RET program is motivated by
this challenge, and aims to support thirty high school through community college teachers in the education of our youth about the interdisciplinary aspects of water research. The intention is that the teachers can then bring these experiences into their classrooms to educate local students about critical water issues. To accomplish this, the Water ECubeG (Engineering, Ecology, Environment, Geosciences) site was developed by an interdisciplinary team of faculty and graduate students. The site is located in a unique region of the world with extensive biodiversity and numerous endemic species. An interdisciplinary research lab at VT coordinates the RET program and an interdisciplinary research institute at the same provides logistical support. The RET site was established after implementing an NSF/REU site for about 10 years, and both sites are operational at the time of this writing.

First we will briefly describe our RET site work, then share assessment findings for the first two years of the RET program. We conducted focus groups with the teachers to garner qualitative feedback for improvement, and gauged how teacher concerns changed over the duration of the annual summer programs. We also assessed teacher concerns with adopting their innovative curricular material into the classroom utilizing an instrument from the Concerns-Based Adoption Model (CBAM): the Stages of Concern (SoC) questionnaire. We also measured participant creative achievement with hopes of correlating achievement in the creative realm to program achievement.

Introduction to the Research Lab

The coordinating lab of the program, the Learning Enhanced Watershed Assessment System (LEWAS) lab, is a unique real-time high-frequency environmental monitoring system established to promote environmental monitoring education and research. The lab has had numerous improvements over the course of 10 years, and been introduced in over 29 courses, across 6 institutions in 3 countries. Contemporaneously, this lab has also hosted an NSF/REU site since 2011.

Professional Development Review

Professional development (PD) is required of many teachers. Teacher PD has been shown to improve student achievement in science, and PD is considered imperative to the realization of standards in curriculum. Teachers are typically required to earn a certain number of continuing education credits (CEUs) as part of their work contract. CEUs may be earned a number of ways, including workshops and courses at nearby institutions, however this can be problematic. One-shot workshops designed for teacher enrichment can be useful, however longer-term PD programs are required to support standards which reach all students. The limitations of the conventional, short-term PD makes a program such as an RET ideal for meaningful curricular change and student growth.

Review of RET Programs

There are numerous RET programs nationwide, only a few of which are focused on water research. A water project in an engineering-centered “RET-E” program at Rutgers introduces green roof design as a project. The RET teachers consider engineering concepts including
water absorption, mass and weight of the roof, cost efficiency, and thermal conductivity for the design exercises. After they’ve designed the roof, the teachers are prompted to amend the design to be usable on an inclined roof. An RET at the University of South Florida titled “RET in Engineering and Computer Science Site: Water Awareness Research and Education” provides research, education, and PD opportunities for K-12 teachers with a focus on management of the nitrogen cycle, provision of clean water, and urban infrastructure improvement [17]. A joint REU/RET site titled “Introducing Critical Zone Observatory Science to Students and Teachers” affords students and teachers the opportunity to conduct research investigating human impacts on the carbon and water cycle via Critical Zone observatories [18, 19]. A project titled “Sustainable Energy, Water and Manufacturing” investigates process constraints on new materials used in semiconductor manufacturing materials from an environmental perspective including water quality and water recycle/reuse [20]. Another project titled “Interdisciplinary Research Experiences for Teachers” gave teachers the opportunity to conduct research in the departments of Chemistry, Geosciences, and Physics, as well as the UWM Planetarium, including research topics such as the development of novel optical fiber sensors for remote environmental monitoring and investigation of antibiotic-resistant bacteria in private drinking water wells [21].

All of the above RET sites are related to water science or environmental monitoring. Our site is unique as it has a high degree of interdisciplinarity: we include fields of study from four major science areas with water-related research: engineering, environmental science, ecology, and geoscience. To the best of our knowledge, our ECubeG site is the only RET site with this level of interdisciplinary collaboration for water research. With regards to assessment of RET programs, an exemplar group has adapted the CBAM assessment model, calling the interview instrument the “Teachers Concerns Questionnaire (TCQ)” [22]. They have found certain trends in concerns over time, and we will compare with our results in this paper.

RET Program Description

The goal of this RET site is to provide teachers (grades 9-14) with an interdisciplinary water research experience and PD. The year-long program is divided into two parts: the six-week summer program and the academic year program. RET participants commute from the school districts near VT to participate in the six-week summer program. Figure 1 shows a map of the locations of the teacher home institutions. An interactive version of this map is in development for publication on our website.

The summer program is designed to accomplish two primary goals: introduce grade 9-14 teachers to the fundamentals of water, research, engineering or experimental design, and to provide opportunities to translate these experiences into curricular material for their STEM classrooms. In the following school year, the teachers are expected to implement their learning activity. They are also welcome to propose university-related field trips and activities for their students.

Summer Program

The summer portion is a six-week program during which RET teachers participate in pre-specified research projects at their assigned labs from Monday through Thursday. Faculty
mentors for the RET site come from four different colleges (Engineering, Science, Agriculture & Life Science and Natural Resources & Environment) and share a common interest in water research. An annotated process flow is presented in Figure 2. The red chevrons show the overall schedule by week, with major milestones called out, while the blue chevrons represent the repeating daily plan which occurs each of the six weeks.

The first day is dedicated to orientation, where the RET teachers are introduced to the site, learn about the study conducted here, and are offered consent forms to participate in the IRB-approved study. In addition to the four-day research period, teachers participate in weekly PD activities and develop learning activities for implementation in their own classrooms. Some titles of research projects which have been implemented are:
1. Iron and Manganese Oxidation Cycles in a Local Drinking Reservoir
2. Using Tracer Studies to Calculate the Dispersion Coefficient of the Webb Branch
3. Enhancing Wastewater Reuse By Using Osmotic Membrane Photobioreactor (OMPBR)
4. Translating Applied Aquatic Chemistry Research to Introductory High School Chemistry
5. Analysis of Nitrogen and Phosphorous in Soil and Water Influenced by Agricultural Practices
6. Interplay Between Disinfectants and Microbial Population in Two Simulated Reclaimed Water Distribution Systems
7. The Search for Microplastics in an Urban Stream
8. Community Composition of Benthic Macroinvertebrates and Water Quality Along A Sediment Gradient in Stroubles Creek

Fridays are reserved for professional development activities and field site visits, which are summarized in Table 1. One PD activity is a visit by curriculum development expert and emeritus of learning science. We discuss various ways to implement their curricular material in the classroom, and dedicate some time to allow them to work on these as a group. Over the course of the summer, teachers tour several real-world water engineering sites, including a wastewater treatment plant, a drinking water facility, and a large hydroelectric dam facility. Teachers also visit other campus research facilities which are not explicitly related to water science: one in biomedical engineering for sport injury prevention, and one in nanoscale engineering, so they might be exposed to some non-water related research at VT.

Table 1: Professional Development Activities

<table>
<thead>
<tr>
<th>Mornings</th>
<th>Afternoons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workshop: Google suite for collaboration</td>
<td>Teacher host lab presentations</td>
</tr>
<tr>
<td>Research summary presentation</td>
<td>Learning activity development</td>
</tr>
<tr>
<td>Dr. Edwards’ (of Flint, MI renown) presentation</td>
<td>Learning activity development</td>
</tr>
<tr>
<td>Workshop: Creating effective group work</td>
<td>Little River hydroelectric dam trip</td>
</tr>
<tr>
<td>Workshop: Scholarship of teaching and learning</td>
<td>Water treatment sites visit</td>
</tr>
<tr>
<td>NSF PIRE workshop with Dr. Pruden</td>
<td>Helmet lab visit</td>
</tr>
<tr>
<td>Mountain Lake geomorphology and karst trip</td>
<td>VT symposium and poster presentations</td>
</tr>
</tbody>
</table>

**Academic Year Program Continuation**

Throughout the academic year following the summer program, teachers are expected to incorporate the learning activity into their curricula. This may entail adapting the original activity they designed in order to fit their curricula, or altering the timing of their activities according to weather conditions (i.e., stream visits need to occur during warm spring months). Some teachers have chosen to collaborate with their peers to carry out conference presentations together, as evidenced in Madden et al. [23].
Assessment

The objectives of the RET program are to provide teachers with PD opportunities, hands-on learning experiences in engineering, ecology, environment, and geosciences, and to support teachers in the creation of curricular material for their students. While our RET program included some community college teachers, they have been dropped from the assessment whenever possible. The only instance this is not possible is in the independently-run focus group study. For the SoC questionnaire we also removed results from individuals who did not complete the SoC at both entry and exit, leaving a sample of nine for year one, and seven for year two. For project evaluation, we ask the following questions:

RQ1. How can we best improve our program, and future programs nationwide?
RQ2. What concerns affect the use of the innovative curricular material, and how do they change from the beginning of the program to the end of the program?
RQ3. What are the levels of implementation of the innovative curricular material?
RQ4. How are creative achievement and learning activity development related?

Three methods are employed to collect data for addressing the above questions: a survey consisting of questions from three sources, a focus group conducted at the culmination of each summer program, and interviews to gauge levels of classroom implementation. All methods are approved by the Institutional Review Board and remain in good standing at the time of administration and dissemination.

Focus Groups

Exploratory focus groups and a short survey were conducted for general improvement of the program and other PD programs. Discerning what the teacher finds important to amend is of the utmost importance since the program is tailored for their enrichment.

To learn the RET teacher’s perspectives on the program, we conducted focus groups with two cohorts of RET teachers at the end of each summer program. Focus groups are considered as effective as individual interviews at less time and labor demands [24]. An assessment expert acted as external evaluator, and was tasked with conducting and evaluating results of the focus group, and evaluating a 14-item survey. The focus group was conducted on the final day of the program each year, at the same site of the program.

Concerns-Based Adoption Model

The second and third research questions are motivated by the need to support teachers in their implementation efforts. To do this, we adopted the Concerns-Based Adoption Model (CBAM) framework [25]. This model was designed to measure teacher concerns with regard to implementing a particular innovation in their classroom. In our case, the innovation is the learning module which they design based on their research experience. The CBAM has been shown to be valid and reliable, and is based around the concept of teacher growth through continual improvement of an innovation [26]. CBAM has previously been implemented in numerous implementations regarding pre-college engineering education, including RET programs [27][22][28].
To address the second research question, we assess concerns related to the adoption of their curricular material. We measure teacher “concerns” and how they change over time [29]. The questionnaire was administered before and after the six-week research experience. By administering twice, we aim to understand how teacher concerns with the implementation of the curricular material vary over the course of the summer program [30]. This same concern was brought up in Laffey et al. [16]. To conduct this analysis, the survey software Qualtrics was utilized, with data management, statistics, and visualization conducted in the language R utilizing the program Tinn-R. The questions were identical to the CBAM questions, and were Likert scaled according to the instrument documentation.

The RET teachers are expected to implement curricular material related to their research in their own course work within one year. To gauge this we implemented the the structured CBAM Levels of Use (LoU) interviews. The seven categories that help to define the levels of use above have been identified as: knowledge, acquiring information, sharing, assessing, planning, status reporting, and performing [26][29]. Asking questions within each of these categories can help assign an unbiased, behavior-based level of implementation to the curricular material. The LoU interviews effectively categorize the distinctive stages of each RET teacher based on behaviors and actions taken, with an overall division between use and non-use, but further categorization within those divisions to describe the complexity of usage.

*Creative Curricular Development*

The development of novel curricular material can be considered a creative pursuit. Creative products are both original and functional; novel and useful [31]. In exploring the intersection between creative achievement and learning activity design, we hope to learn how the two correlate. In principle, the best predictor of future creative behavior is past creative behavior [32].

To address RQ4, we asked for self-reports of past acknowledgment through the simple and objective Creative Achievement Questionnaire (CAQ). The CAQ is a survey of the RET teacher’s lifetime creative accomplishments, administered only once as there is relatively little time in the six-week research experience compared to a lifetime. The CAQ assesses ten creativity domains of visual arts, music, creative writing, dance, drama, architecture, humor, scientific discovery, invention, and culinary arts [33]. The scores of lifetime creative achievement are garnered by summing to find a total CAQ score. We had initially postulated that teachers would grade highly on CAQ as a result of their willingness to create and develop curricular material in a number of different ventures. The CAQ has been shown to be valid and reliable in a large multistudy work [33].

*Results and Discussion*

The fourteen-item survey instrument was evaluated externally by an assessment expert. These results find that teachers from both summer cohorts have become more aware of how scientists from different fields collaborate to conduct research, and how to integrate different disciplinary perspectives into their research work. The teachers demonstrated an improved confidence in conducting research independently. Increased confidence is a positive result which is evidenced
by the teachers gaining agency through their experience. Unfortunately, decreased confidence was found regarding communicating research findings in oral and written forms. This may have been due to a lack of familiarity with research reporting requirements and poster design. The two cohorts to date have diverged on numerous other reported results, so they are not presented here.

*Stages of Concern (SoC)*

The CBAM SoC reveals concerns toward the learning activity and its implementation vary over the course of the RET summer program. These results were amended to exclude results for the participants which teach community college courses, and operations on the data were conducted in two groups: pre-program and post-program. Data was first grouped according to the six stages of concern, then the average across all teachers for the two cohorts was taken. The relative intensity of the concern stages is presented, which is obtained by going though the SoC scoring device presented in the CBAM manual. The results of the SoC pre- and post- summer program are presented in Figure 3. The plot provides a visual representation of how the teacher concerns with the curricular material implementation changed as a result of the RET program, and the PD gained through it.

The categories of “Management” and “Refocusing” both notably increased over the six-week experience. The increased concern of management may be due to the shift during the summer program from becoming acquainted, then conducting research, then considering how the research might be implemented in their own classes. While they should be considering both equally throughout the program, we found that many teachers prioritized implementation issues later in the program. Similarly, the refocusing category should intuitively increase with time in the program. As the name implies, refocusing regards making major changes to the innovative implementation, effectively changing scope. Note this category is also of the least concern to the participants at the start of the program. These results are intuitive and to be expected: at the beginning of the experience, there is little foundational work completed on the classroom implementations. Thus, there is nothing from which to re-focus; rather the teachers would be more concerned with initial development and integration work related to the other categories.

Teachers were found to be much less concerned with the innovation overall at the end of the program. This is evidenced in the “Unconcerned” category of survey questions. This is understandable and intuitive as there may be some initial uncertainties which diminish as the program is experienced and progress is made over the six weeks. Teacher concerns in the stages of information, personal, consequence, and collaboration did not meaningfully change over the course of the program.

*Levels of Use (LoU) Interviews*

Interviews following the summer experience were conducted with teachers at varying times. Preliminary results less than one semester following the summer experience showed little implementation in the class, so further questioning was delayed. Structured telephone interviews were performed according the CBAM. These interviews were conducted were conducted over a
period of one week, which took place three semesters after the first cohort experience, and one semester after the second cohort. As such, these results are not indicative of long-term results, and produced a skewed result in favor of those who had more time to prepare and implement.

At the time of this writing, thirteen interviews have been successfully performed, gauging the level of curricular implementation for those participants. The results were largely positive, with all but two respondents having implemented in their classroom. A tabulation of the level of implementation at the time of this writing can be found in Table 2.

Ideally all participants would have implemented and made efforts towards improvement, however we did not realistically expect this to be the case. Teacher reported having to contend with weather for outdoor activities, prioritizing state standards work, and managing logistical issues as impediments to implementation. Still others are looking for staff assistance for extracurricular clubs (robotics) and are seeking out external grant opportunities to fund their implementations. Teachers who have brought the novel curricular materials into the classroom report improved outcomes for student engagement and interest in the material as a result of the implementation.
Table 2: Levels of Use Interview Results

<table>
<thead>
<tr>
<th>Level</th>
<th>Level of Use</th>
<th>Description</th>
<th>Number of teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Nonuse</td>
<td>Little to no action</td>
<td>0</td>
</tr>
<tr>
<td>I</td>
<td>Orientation</td>
<td>Information gathering</td>
<td>0</td>
</tr>
<tr>
<td>II</td>
<td>Preparation</td>
<td>Preparation for first use</td>
<td>2</td>
</tr>
<tr>
<td>III</td>
<td>Mechanical Use</td>
<td>Use w/o reflection</td>
<td>1</td>
</tr>
<tr>
<td>IV A</td>
<td>Routine</td>
<td>Reliable use with few changes</td>
<td>4</td>
</tr>
<tr>
<td>IV B</td>
<td>Refinement</td>
<td>Continual adaption &amp; improvement</td>
<td>3</td>
</tr>
<tr>
<td>V</td>
<td>Integration</td>
<td>Collaboration w/ others to improve</td>
<td>3</td>
</tr>
<tr>
<td>VI</td>
<td>Renewal</td>
<td>Large improvement &amp; reevaluation</td>
<td>0</td>
</tr>
</tbody>
</table>

**Teacher’s Creative Achievements**

Creative achievement was found to be low with the sample of RET teachers in the first cohort. The second cohort included much more lifetime creative achievement and recognition, with two teachers scoring over ten on the instrument. While the overall creative accomplishment of some teachers is low, we are not dissuaded by the result, as individuals with high creative achievement have been found to be quite rare [34].

We hypothesized that teachers who would choose to participate in a program to develop and implement innovative curricula would be creatively accomplished; that their past creativity would be an indicator of future creative accomplishment as indicated by [32]. Our analysis has not found any relationship between the levels of implementation and creative achievement for this small sample. However, the individual with the highest CAQ score has implemented their curricular work in three separate projects at their school. This is a unique endeavor among our sample, especially for a member of the most recent cohort who has had only one semester to implement.

**Focus Group Analysis**

A focus group was conducted at the culmination of each summer program. These results show teachers found the summer program to be beneficial, and they were enthusiastic about the experience. When asked what they most enjoyed about the program, wide agreement was had on the following comment:

We got to do things we would not normally get to do, like setting up the experiment and going out into the field. These are normally outside of the parameters of what we get to do in our usual jobs. That was enjoyable.

One teacher expressed gratitude with the possibility of earning PD credit and money at the same time:

Somebody is paying us for professional development for a change, like other professions, rather than us having to pay for our professional development. It’s nice to be treated like a professional...
Teachers praised the efforts of their host lab mentors, graduate students with whom they conducted research, and university staff as well:

It was surprising how many people outside of the program who were tremendously helpful as well. There were many networking opportunities that led to others who are now helping us work with the schools. ... We found people at (Virginia) Tech willing and even eager to help us. We can see bringing our students back to visit some of the labs from Friday site visits.

We reserved Fridays for specific PD activities and field trips. Teachers have made a point to arrange future campus visits for their students to explore the labs and facilities they had the opportunity to visit and work from over the course of the summer. Some had already made arrangements to visit campus with their students on the culmination day of the RET program.

I did like the field trips. It is not always easy to get access to those places.

With regard to field visits, the teachers expressed want for visiting the workplaces of other teachers in their cohorts. As a response to a prompt for improvement of the Friday activities, one teacher expressed:

Tour somebody else’s labs. Allow more time for collaboration with other teachers, share what we are doing, what’s working and what’s not. More time for science.

Notable accomplishments to date

Two presentations have been made by an Engineering Education doctoral student at conferences regarding this work. We are also proud to say that all teachers have presented their work at a university-sponsored research symposium, where they shared posters on their research to students, other researchers, and the public. Our RET teachers have earned grants in excess of $5000 to support their implementations, earning numerous news media mentions as well.

Future work

We are currently designing a platform-independent, interactive map which represents the teachers, their work, and service area on the internet. We have recruited the most accomplished teachers to return in our third year to take a role as master teachers. These teachers will expand on their previous research and assist other teachers with their own curricular development to prepare for final publication to www.teachengineering.org. We will document at least twenty curricular pieces.

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