Major Goals -

The goal of this project is to develop and educate a diverse workforce effective in careers that are directly related to geospatial technologies (GSTs) or that employ spatial tools and skills to visualize, analyze and communicate. Utilizing STEM teaching and learning best practices, GSTs are introduced to educators who are supported as they integrate GSTs into community college, high school, and university classrooms. The GEOCACHE project builds upon lessons learned about professional development for educators from the POD Project (DRL #0929846, Sample, et al.), in order to increase teachers' abilities to teach with geospatial technologies. We will create pathways that allow students to obtain competency in GIS at a level complementary to their career and/or educational goals.

ACCOMPLISHMENTS UNDER THESE GOALS

Major Activities

Continued professional development was a major focus for this reporting period. Our goal for the professional development was to support lesson implementation for the 11 college faculty and 9 high school teachers who completed the 35 hour Advanced GEOCACHE Professional Learning Institute in summer 2015. This support was offered through phone calls, classroom site visits, emails, face-to-face and online meetings, and other just-in-time interventions. We elaborate in the appropriate sections of the report.

Additional activity this reporting period included measuring our progress toward meeting our objectives (1 – Course Pathways and Articulation; 2 – Professional Development; 3 – Student Learning; 4 – Career Awareness and Attitudes). We worked closely with educators, our evaluators and partners at Mesa Community College to gather and analyze data toward that end. We also supported educators to attend and present at conferences to buoy their leadership capacity. More details are provided below and in the attached evaluation report.

Specific Objectives

We report on Objective 1 – Course Pathways and Articulation here. Objectives 2 (Professional Development), 3 (Student Learning) and 4 (Career Awareness and Attitudes) in great detail in other areas of this report.

Our partners were successful in getting the Maricopa County Community College Curriculum office and the Geography Instructional Council to approve a dual enrollment Introduction to Geographic Information Systems course in 2014-2015 and teachers expressed an interest. However, since community college instructors in Arizona are now required to have at least a master's degree in Geography in order to teach that course, and few teachers in Arizona are qualified, it was not offered in high schools this year.

Though they are not offering the courses for dual enrollment, we are excited that high school faculty are integrating GST activities into existing courses and providing more students opportunities to learn about GST. One high school teacher offered a GIS elective that introduced students to advanced GST skills including Python coding. We expand on NAU's plans to help meet this objective later in the report.

Significant Results

Objective 3: Student Learning

To measure our progress toward student learning, the GEOCACHE team analyzed participant lesson plans, participant questionnaires, classroom observations, student questionnaires, and student work samples. Details on methods and instruments are provided in the attached Evaluation Report. Highlights and excerpts are included here. We report on career awareness and attitudes under Key Outcomes due to the character limitation.

Commented [NEB1]: Because the focus of geocache this year was on classroom implementation with students following PD, student data was a focus for data collection and analysis. Why are the career awareness results not listed here?

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Lesson Plans

At the end of the school year, 15 cohort 2 educators submitted lesson plans. The plans were varied, from identifying what geologic hazards threaten homes in the US, to where is the best place to locate telescopes to how can we improve access to healthy foods for people in our city. The professional development team had stressed creating lessons that were tied to curricular goals in the class.

A rubric was used to analyze the quality of the lesson plans. The PI and internal evaluator identified 5 areas upon which to focus: 1. The extent to which examination of spatial data using GST was appropriate for accomplishing curricular/course goals; 2. The extent to which the lesson was designed to support conceptual understanding of important concepts in targeted course; 3. Identification of a challenging, authentic, question; 4. Whether lesson is of appropriate length to provide students time to develop conceptual understanding; and 5. The extent to which the final product and assessment emphasized argumentation using spatial data as evidence for student claims.

Analysis of lesson plans indicates the majority of participants were able to develop lessons that that aligned their curricular goals with GST, developed conceptual understanding in students, provided opportunities for students to participate in an authentic problem or lesson and developed understandings, skills and abilities over time. More educators had challenges with assessment of student learning.

Lesson Implementation and Student Benefits

The internal evaluator surveyed Cohort 2 participants about their experiences implementing their lessons. There were 15 respondents. Fourteen educators reported they taught the lesson they created at the Advanced Institute or a modified lesson, with 626 students, grades 9 to post-secondary, participating in GST lessons this year. The average lesson time was 9.1 hours. Six of the lessons were for 5 or fewer hours and 8 of the lessons were for 6 to 20 hours. About one-third of the educators identified that they could have used more class time on the lesson. Four educators reported that they deviated significantly from the lesson they had planned in the Advanced Institute.

Evidence from the plans and an associated educator reflections on implementation identifies that seven educators implemented lessons as designed in the summer institute and another eight made significant modifications. Some modifications were because of technology challenges.

Overall, educators were positive about the value of the experience for their students. They found that use of GST both enhanced subject matter and engaged students. Other values identified included opportunities for students to communicate ideas visually, opportunities to utilize complex technology, opportunities for communication of claims using evidence and opportunities for use of 21st century skills.

As in years prior, the evaluation team observed classroom lessons and used the ICOT protocol to score the lessons for evidence of classroom characteristics, pedagogy and ISTE standards. The observers visited classrooms of 13 teachers. The lessons observed did not have common lesson plans, but all involved using geospatial data and ArcGIS Online. A summary of observations identified that after professional development, educators were able to create lessons that addressed relatively large numbers of indicators for the ISTE Standards for Students. Instructors had students work as individuals or in small groups; whole class instruction was a small part of the class time in most observations. The teacher was most commonly in the role of facilitator, with a relatively small part of observations spent in presentation and management. Students used technology tools for much larger proportions of the observed periods as did teachers; in some lessons, students accounted for all the technology use.

A survey to assess student experience with 21st century skills through classroom projects was modified from Baker & White (2003) and was administered in the 2015-2016 school year. The students of eleven instructors, 32 high school students and 107 college students, completed at least half of both the pre and post questionnaire.

Questionnaire findings indicated that participating in the lesson gave students new opportunities to use GST. Before the lesson began about one-quarter of the high school students had used GIS, primarily within the classroom of one teacher. At the end of the lesson 100% of the high school respondents reported that they had used GIS. At the beginning of the lesson only 6% (6) of the college respondents had used GIS. At the end of the lesson, 80% of the college respondents reported that they had used GIS. The other 20% of the college students reported that they had used a map within a browser.

Findings indicated that more students used GST in different ways during the lesson. After participating in the lesson the majority of high school students reported that they had used GST to explore the software, generate their own data or create a map by adding layers. Interestingly, fewer reported using GST for spatial analysis. There was a large increase in college students' uses of GST through participation in the lesson, and they reported more increase in use of GST in different ways than high school students.

Prior to participating, about half of the students reported that they had worked on a project in a class. After the lesson, 3/4 of the high students and almost all of the college students had worked on projects. Because the team reduced implementation requirements for participating educators from a unit to a lesson, and did not require implementation of a full project this year (see Key Outcomes), it is unsurprising that not all students had opportunities to work on projects. Nevertheless, the majority of students did have this opportunity.

Students were asked to identify their abilities to use or analyze maps or data before and after participating in the lesson, as measured on a 4-point scale. The resulting means indicated that students expressed moderate abilities to use and analyze maps and data at the beginning of the lesson. A dependent t-test was conducted to identify if students perceived any changes in their abilities after participating in the lesson. There was no significant change in high school students' perception of their abilities to use or analyze maps or data at the end of the GST projects ($p > .05$). For college students, there was a significant effect for their capability of using a map to analyze data, $t(104) = 2.44$, $p = .02$ and making a claim based on spatial data, $t(104) = 3.06$, $p = .003$, with the post-program scores higher than the pre-program scores. These results indicate that participating in lessons supported opportunities for the college students, more academically advanced than high school students, to develop GST specific skills, but not more general skills.

Thirteen educators submitted samples of student work for analysis. Quality and level of use of GST varied. Student work was dependent on the assignment presented by the instructors. The reviewer looked for evidence that GST was used to show a relationship or pattern in spatial data. All of the submitted student work from three educators demonstrated that GST was used to show a relationship or pattern in spatial data, some of the student work from seven of the educators demonstrated such and none of the student work submitted by three educators demonstrated that GST used to show a relationship or pattern in spatial data.

Key outcomes or other achievements

Professional Development

GEOCACHE was focused on helping teachers integrate GST and project based instruction (PBI). However, after reflecting on the implementation rate of the cohort 1 participants, it was determined that expecting teachers who are completely new to both GST and PBI to integrate the two for their initial lesson might be too ambitious.

The leap to GST-integrated PBI takes time, even with significant support. For example, the teachers with whom we worked in another project (DRL 0929846) did not implement projects until they had participated in 70 hours of PD, implemented a project we provided, and attended an additional 35 hours of PD to design their own lessons. In contrast, the participants in this project experienced only 59 hours of required PD and optional follow up support.

Our theory of action relies on lesson implementation. Therefore, although we encouraged teachers to plan a PBI unit, we gave them permission to implement only portion of it, with the understanding that they would implement more of the full project each year. The idea was asking them to implement one lesson would not seem as overwhelming as the prospect of implementing a long term project. This took some of the pressure off those who were tentative, yet was open-ended enough to allow more ambitious teachers to implement a PBI unit. Evidence indicates that reducing requirements was a more effective model. In comparison to cohort 1, our implementation rate was much higher, and students had many more learning opportunities (see Significant Results).

Educators identified resources and the Advanced Institute as important for their ability to implement. Eleven educators received follow-up support from the project team and others participated in follow-up sessions. Educators also found Esri products and their own self-study as important for implementation.

A high school teacher and a community college instructor accompanied the PIs to the ATE Principal Investigators Conference. They had the opportunity to network and presented information at the GEOCACHE Showcase Table. The high school teacher shared challenges and successes with project implementation, and the college instructor offered suggestions on assessing group projects. The PI addressed how PD offerings changed in response to needs of educators, our evaluators shared the classroom observation tool and how it has changed in response to program needs, and the MCC PI shared lessons learned when trying to implement a dual enrollment course.

Two participants, a high school teacher and a community college instructor, co-presented with the PI at the Esri Educator and User Conference. Participants gained insight about how other fields utilize GST as a core tool. They also shared their experiences with educators in a paper session.

Several participants attended additional PD focused on GST. One high school teacher attended the NGTC Geospatial Technology Summer Workshop, offered by the National Geospatial Technology Center of Excellence, which resulted in GST-integrated lesson plans. He credited GEOCACHE as providing him with the inspiration to apply, because of his positive learning experiences with like-minded educators, and a desire to continue with a professional learning community interested in integrating GST in the classroom. He also stated that GEOCACHE provided him with foundational GIS skills that were necessary for the application.

A community college instructor and a high school teacher applied and were invited to Esri's Teachers Teaching Teachers GIS (T3G) Summer Workshop. T3G is a PD event for educators and education influencers who help other educators learn why and how to use GIS. Participants boost their skills in teaching with and using GST and conducting PD. They are expected to share their learning through at least one workshop to others.

Another high school science teacher enrolled in an online course offered by Esri called "Going Places with Spatial Analysis. She credits GEOCACHE with igniting her interest to learn more about GST and GST careers.

The following quotes demonstrate how participants are extending the reach of the project through further education or outreach:

… without [GEOCACHE] I would have missed a great training. Where I work is very rural and I do not believe I would have any knowledge of [T3G]. I would have not had many of the basic skills that were needed to gain the most from the event. Some of the material covered was review from GEOCACHE.

While I have not had the opportunity to present at additional PD events I am mentoring my department on GIS and we just opened 2 different environmental classes which will be using GIS for many different aspects of their curriculum. The district mandated STEM in the district and I was uniquely qualified to train the Science Department in this technology. I intend to demonstrate GIS at a district wide PD event soon.

GEOCACHE was instrumental in jumpstarting my practical use of GIS in the classroom. I was able to move forward with a microbiology project that required GIS mapping of data and subsequent spatial analysis by my students. Without GEOCACHE I would not have completed this project, nor would I have presented this project at the ESRI educator's conference in July 2016.

GEOCACHE also is responsible for my applying for and acceptance into the T3G institute July 2016. The GEOCACHE instructors kept the group aware of ESRI opportunities and GIS education information, allowing me to see a wide variety of available professional development opportunities.

I would have been extremely challenged at the T3G institute without GEOCACHE to provide me with a working knowledge of basic GIS knowledge and AGO technical skills. I also have completed several ESRI online courses that GEOCACHE directed me to.

GEOCACHE provided me with the technical skills and the idea of problem-based learning for my project. Discussing the project with peers and instructors helped guide me …I successfully implemented the spatial analysis project in the classroom, allowing me to discuss successes and pitfalls at the ESRI educator's conference.

I have never been to an ESRI conference so it was a revelation for me to see the technology and other projects that educators are working with. I was able to network …. GEOCACHE and T3G have given me the confidence to begin recruiting more biology instructors to begin using AGO.

Career Awareness and Attitudes

Nine educators (more than half the respondents) reported discussing careers using GST with their classes.

A survey to assess student career interest in GST was administered. Thirty high school students and 105 college students of 11 instructors (three high school teachers and eight college instructors) completed both the pre and the post- questionnaire.

Students were asked about their awareness of STEM or geospatial careers before and after participating in the lesson. More students were aware of STEM careers than GST careers at the beginning and ending of projects. A dependent t-test was conducted to identify if student awareness changed after participating in the lesson. There was no significant change in college students' awareness of STEM careers but there was a significant increase in their awareness of GST careers after participating in the lesson $t(104) = 5.331$, $p = .000$. There was no significant change in high school students' awareness of STEM or GST careers after participating in the lesson.

Students were asked about their interest in STEM or geospatial courses or careers before and after participating in the lesson. A dependent t-test was conducted to identify if interest changed after participating in the lesson. There was no significant change in high school students' interest in STEM or GST careers or interest in courses to learn about GST or involving real world projects after participating in the lesson. There was no significant change in college students' interest in STEM or GST careers or

interest in courses to learn about GST, but there was a significant decrease in their interest in taking classes involving real world projects after participating in the lesson $t(104) = 2.447$, $p = .016$.

What opportunities for training and PD has the project provided?
To support cohort 2 participants as they implemented geospatial projects, participants were surveyed to determine needs. Based on responses, one face-to-face training and one all day webinar were scheduled (October, February). Twenty-eight educators from both cohorts were invited to participate.

An all-day session was held in October 2015 at Mesa Community College. Eight cohort 2 participants attended. During the session, participants shared challenges and successes, reviewed and learned new GST skills, and received focused support for the lessons they would be implementing. Two participants shared some of what they learned from attending the Esri Education User conference and all were invited to attend the AZ Geographic Alliance meeting nearby which offered additional presentations from Esri educators and two cohort 1 participants. Feedback on this session was very positive. The participants enjoyed connecting with others learning to incorporate GST into existing courses and they appreciated the opportunity to refine their technology skills and the personalized help.

Following this session, an online survey was conducted to identify educators' perceived needs and preferred format for additional support. Nineteen educators responded to the survey. More than half of the respondents requested support managing, preparing and serving data through student use. Other identified topics for follow-up support were overall GST use, support for teaching with ArcGIS, and to learn something new. Educators also identified specific challenges they were having, with organizational accounts, sharing maps and other technical challenges, as well as pedagogical challenges with project-based instruction. More than half of the respondents identified that they would be able to participate in another face to face meeting, however, a convenient date and location for such a meeting could not be established to meet all participant needs. Ultimately, a synchronous online meeting format was chosen and scheduled for February 2016. We shared an agenda including discreet times so that participants could attend the sessions that most met their needs. The session was also recorded to provide access to participants who could not attend live.

The sessions for the meeting were developed from needs identified by educators in the online survey. These included reviewing ArcGIS Online (AGOL), teaching with AGOL, and managing, preparing and serving data for student use. Time for individuals to get help was also available. Seven educators participated, one from cohort 1 and six from cohort 2. Five interactive sessions were facilitated by the project team and participants could enter or exit the webinar as needed. All participants stayed for the entire webinar. At one point, one of the participants "took control" and led the learning for the group based on her experiences.

How have results been disseminated?
As mentioned previously, a high school teacher and a community college instructor accompanied the PIs to the ATE Principal Investigators Conference and presented information at the GEOCACHE Showcase Table. The high school teacher shared challenges and successes with project implementation, and the college instructor offered suggestions on assessing group projects. The PI addressed how PD offerings changed in response to needs of educators, our evaluators shared the classroom observation tool and how it has changed in response to program needs, and the MCC PI shared lessons learned when trying to implement a dual enrollment course. Additionally, the external evaluator demonstrated the instrument refined through the project, the Classroom Observation Tool.

At the Arizona Science Teachers Association meeting in November, we presented our GEOCACHE theory of action, and some examples of how teachers and students are using geospatial technology to explore authentic local problems. We stressed the importance of spatial thinking in STEM disciplines. We helped teachers learn where to obtain a free account and some of the teaching resources available to them at no cost.

In January, at the Integrate to Innovate STEM Conference in Phoenix, we presented how the GEOCACHE model influenced our new ITEST project. We expand on this further in the Impact section of the report.

Two participants, a high school teacher and a community college instructor, co-presented with PI Rubino-Hare at the 2016 Esri Educator and User Conference in San Diego in June 2016. The Esri Educator Conference is a forum for educators in the field of geospatial technologies to learn from each other about innovations and resources affecting the instruction of geospatial technologies or the integration of these technologies into the classroom as a tool for teaching content. They shared their experiences integrating geospatial technologies into the classroom for the first time in a session entitled: ***Incorporating GIS into STEM and General Education***. One other community college instructor shared her experiences. She was not able to attend but PI Rubino-Hare presented on her behalf.
http://proceedings.esri.com/library/userconf/educ16/papers/2004_562.pdf

Recently, the GEOCACHE program model was highlighted as an effective professional development program in a report developed by the American Association of Geographers in support of an Advanced Placement Geographic Information Science and Technology course (see attached).

Plans during the next reporting period to accomplish goals?
We made great progress supporting college and high school teachers to implement GST lessons in their existing courses to inspire students to enter GST careers. We'll support teachers through another year of implementation helping those who had success refine lessons and increase skills. This year we will continue to identify barriers and provide additional support to those who were not able to implement.

To increase sustainability and disseminate results, we will focus on building participant leadership capacity. We will support teachers to present at GIS education conferences and other venues and our collaborators at MCC will submit the resulting products to the ATE Central Archive. We'll host a regional conference where participants and their students can celebrate their successes and inspire others from the AZ Educators GIS Users group which will be supported by our collaborators at MCC. We envision inspirational talks similar to those at the ATE PI conferences, with breakout sessions to support GST & pedagogy skills. We hope to broaden the reach of the GEOCACHE project.

For continued professional development of the GEOCACHE team, the PI attended a Design Based Implementation Research conference. This research approach engages teams of stakeholders identify a problem of practice, commit to iterative, collaborative design, develop theory related to classroom learning and implementation through systematic inquiry, and develop capacity for sustaining change in systems. This approach is very well aligned with the future direction for GEOCACHE. We plan to apply learning from this conference during the AZ Education User Conference we will host in 2017. We will invite stakeholders from around AZ to collaboratively identify problems of practice and identify changes we can implement to sustain the positive progress we have made with the GEOCACHE project. We will

continue the conversation through the AZ Education User Group our partners at MCC will establish and support.

Northern Arizona University is recently, under the guidance of their new President, committed to supporting pathways to the University from high schools and community colleges. This year we will work closely with Dean of Social and Behavioral Sciences to work through barriers that have impeded our progress towards achieving dual enrollment for high school and college courses.

Supporting Files (limit 5 @5GB each):

- Evaluation Report
- AP GIS & T

PRODUCTS

Summary for current report (details follow summary):

Publications (New):

- Conference Paper / Presentation. Hare, L., Cheepurupalli, R., Ortiz, E., Wellner, K., Bloom, N. & Bielefeldt, T. (2016). New Experiences Teaching Projects with AGOL. Esri Education User Conference. San Diego, CA.

Websites: Nothing new

Other Products: 1

Other Product Audio or Video Products

Recording of Webinar Feb 3, 2016. https://connect.maricopa.edu/p4ynigbdirk/

- (0:00:00) Review of ArcGIS Online – Karen Blevins lead
- (1:28:52) Teaching with ArcGIS Online – Mark Manone lead
- (3:04:15) Managing Data for Student Use in ArcGIS online – Karen Blevins lead
- (4:12:55) Preparing and Serving Data for Student Use in ArcGIS online (including apps) – Mark Manone lead

IMPACT - What is the impact of the project? How has it contributed?

The project is significant to pedagogical methods relating to integration of geospatial technologies into the classroom and the professional development strategies that support that integration.

The principles of effective project-based instruction and 21st century skills teaching and assessment were new to many participants. Several noted that the resources provided were invaluable for developing their units and these tools and instruction had an impact on their teaching strategies as evidenced by student survey responses and sample work, classroom observations and lesson plans.

Lessons learned from GEOCACHE are crucial to our new NSF-funded ITEST project, DRL 1513287, Expanding Geospatial Technology Career Development for High School Students through Teacher Professional Development: The Power of Data Project. We are currently conducting a study using design-based research to better understand what elements of PD are essential, in what contexts teachers are able to implement GST-integrated lessons and achieve high levels of student results, and what factors help students develop interest in STEM and GST careers.

What is the impact on Human Resources

As described in Key Outcomes and Other Achievements, several teachers took advantage of additional professional learning opportunities including attending the ATE PI Conference and attending and presenting at the Esri conference, where they interacted not only with educators teaching with GST but also with other GST professionals, thus expanding their awareness of careers in GST.

Several teachers attended GST PD offerings and courses, where they further developed their skills and abilities in GST and in leading others to teach with GST.

What is the impact on society beyond science and technology?

GST can be utilized in many academic fields. Teachers outside of STEM disciplines participated in GEOCACHE PD and have shared it with others. Teachers in many disciplines can utilize the materials GEOCACHE has developed for improving their teaching and exposing more students to GST as a career option.