Abstract Title: Student Achievement and the Participation of Rural High School Chemistry Teachers in a Multi-Year Professional Development Program with Special Emphasis on the Use of Computational Tools.

MSP Project Name: Institute for Chemistry Literacy through Computational Science (ICLCS)

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120 word summary:

The ICLCS program for rural high school chemistry teachers provides professional development in content knowledge, pedagogical skills, and computational science teaching tools. It is provided over the course of three years, via an intensive two-week residential institute each summer in addition to a virtual professional learning community through which teachers take an online chemistry course every year and have access to university mentors (participating faculty). Results show that ICLCS is a powerful intervention that increases teachers' content knowledge and use of computational science teaching tools and that that is reflected in higher student scores on the American Chemical Society's exam. Student post-test scores and pre- to post-test gains have improved with each year of intervention received by teachers.

- Section 1: **Questions for dialogue at the MSP LNC**.

1. Since Cadre III teachers are beginning the ICLCS intervention with higher levels of computer proficiency and content knowledge than their predecessors, will they still reap incremental benefits in all three years of intervention?

2. What is the best way to scale ICLCS best practices using a blended learning approach?

3. What are the implications for professional development for veteran and pre-service teachers? (i.e. length and duration)

4. How does this research impact STEM teaching and learning in the near future? (getting it into the curriculum)

- Section 2: **Conceptual framework**.

The use of computational science tools to model and visualize complex phenomena and processes has become standard practice among researchers because such tools help them to better understand and explain the phenomena and processes of interest. It is reasonable to extrapolate that the use of computational science tools in the classroom would help secondary students better understand complex phenomena and processes, resulting in higher student achievement. Related research, though limited, is supportive. For instance, Tinker and Xie (2008) found that the ability to "see" phenomena helps students understand chemical principles and increases their interest and enthusiasm, which should boost student achievement. Computational science tools can also facilitate more active learning, such as enabling students to "discover" physical laws by changing parameters in a simulation, which Prince (2004) found to be an effective educational method.

For computational tools to improve student achievement they must be employed in pedagogically sound ways, and for their use to significantly impact the field of secondary STEM education, high quality computational science tools must be readily and cheaply available to teachers and be sufficiently user-friendly. The Institute for Chemistry Literacy through Computational Science (ICLCS) program provides training in such computational science tools that are of use to chemistry teachers. The ICLCS program also entails additional professional development to ensure that teachers become well equipped to take full advantage of the computational science tools. More specifically, over the course of three years ICLCS provides 350+ hours of professional development to rural high school chemistry teachers. The goals of the intervention are to increase teachers': (1) mastery of chemistry content knowledge; (2) pedagogical/curriculum development skills; and especially (3) use of computational science tools in the classroom.

One expected outcome of ICLCS is *increased student achievement*. That is conceptualized partly as gains in the ability to employ computational tools, but primarily as gains in the knowledge of chemistry and the ability to apply general chemistry principles and, more broadly, the scientific method, as a process for investigating phenomena and learning new knowledge. This presentation focuses on student achievement specifically related to chemistry. It is hypothesized that student gains, as measured by Part I (40 items) of the American Chemical Society's (ACS) student exam, will be greater for students of teachers in the cohort with more years of ICLCS intervention. This measure was chosen because the American Chemical Society is the premier chemistry organization in America, and the student and teacher tests we employ are developed by the ACS Division of Chemical Education Examinations Institute, whose mission is to develop and nationally distribute chemistry assessments.

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- Section 3: **Explanatory framework**.

ICLCS employs a quasi-experimental, multiple baseline research design. There are currently three cohorts of teachers, known as "Cadres." In the first project year (2007 – 2008), students in both Cadres I and II took the ACS student exam as a pre- and post-test, but only Cadre I teachers received professional development. The ICLCS intervention began in Cadre II in the second project year. In the third project year (2009 – 2010), Cadre I was in its third and final year of intervention, and Cadre II was in its second. That was the baseline year for Cadre III members, so they received no professional development though, just as in Cadres I and II, the teachers took the American Chemical Society's teacher exam, and their students took the ACS student exam.

The ICLCS professional development intervention uses a blended learning approach that begins with an intensive 2-week residential professional development institute that is developed based upon a needs assessment by participants in the spring of each year. No "teaching to the test" is conducted. During the school year, professional development continues via a virtual professional learning environment, which allows cadre members to communicate with one another and obtain online mentoring support from faculty members at the University of Illinois at Urbana-Champaign (UIUC) who are available to answer content questions and provide help with computational tools and curriculum modules that the teachers work on in cross-district teams. Each year teachers also earn 3 graduate credit hours by taking a specified course online (e.g., Molecular Dynamics in the second year of intervention, and Organic Chemistry in the third).

The **first 2-week ICLCS Summer Institute** provides a total of approximately 79 hours of professional development: 21.5 hours in computational chemistry (Excel, ChemSketch, and WebMO); 6.5 hours of other technology; 10 hours of chemistry content refreshers; 8.5 hours of pedagogy and leadership; and 15 hours of curriculum development.

The **second ICLCS Summer Institute** provides a total of approximately 76 hours of professional development: 27.5 hours of computational chemistry; 4 hours of other technology; 12 hours of chemistry content refreshers; 14.5 hours of pedagogy and leadership; and 16 hours of curriculum development. In addition to learning new uses of the computational science tools presented in the previous summer institute, teachers are introduced to Vensim PLE, a systems dynamic program for modeling time-dependent phenomena. All tools and resources are freely available to teachers.

The **third and final ICLCS Summer Institute** provides a total of approximately 78 hours of professional development: 20 hours of computational chemistry; 10 hours of chemistry content refreshers; 13 hours of pedagogy and leadership; and 18 hours of curriculum development. The primary goals of that institute are to: (1) introduce two new computational tools (Odyssey and Molecular Workbench); (2) provide additional real-life examples of how computational tools can be used in the classroom, through teacher-led micro-teaching sessions; (3) give teachers time to incorporate computational chemistry into their curriculum; and (4) follow up on instruction on best-practices and leadership given at prior institutes.

Although the basic program remains essentially the same, improvements and adjustments are made based on periodic assessments of teacher needs and their feedback. Prior to the very first summer Institute, a needs assessment was sent to all participants in both beginning cohorts. From the survey, we learned that over 60% of teachers were teaching *out of field*. Using this data, we designed a program to meet the needs of teachers, which included content development in specific areas, models of inquiry teaching, and leadership training, to name a few. **The findings from our evaluator surveys and test analyses are used to make adjustments to the program content, instruction, selection of computational tools, and changes to the PLE and general support of participants.** As partners, the ICLCS teachers are actively involved in helping us design an effective program.

In both Cadres I and II, teacher self-reports (online surveys) have indicated **significant increases in use of computational science tools, and teachers' mean scores on** the 50-item American Chemical Society's **teacher exam have continued to rise. Thus, both cadres have made incremental improvements every year in the areas targeted by the ICLCS intervention.** As expected, **in any given year Cadre I (one year further along in the ICLCS program) has done better.**

At the end of the **second project year (2008 – 2009)**, during which the 55 Cadre II teachers received their first year of intervention, and the 37 Cadre I teachers their second, **Cadre I students continued to show significantly greater gains than did Cadre II students, just as they had after Year 1 ($p < .001$).** Although the students of Cadre I teachers tended to have begun the 2008 – 2009 academic year with significantly less content knowledge than their peers taught by Cadre II teachers ($p < .001$ in an independent samples t-test), students in the two groups finished their courses on a par with one another. The post-test mean percentage of correct items on the American Chemical Society's (ACS) student exam was 36.7% in both cadres.

In the **third project year (2009 – 2010)**, results were disaggregated for the first time by the type of chemistry course, differentiating among Honors or "regular" Chemistry I and Chemistry II classes and Advanced Placement (AP) classes (N = 3106 students with pre- and post-test scores). In that year, Cadre III received no intervention; Cadre II was in its second year of intervention; and Cadre I in its third. The Games-Howell procedure compared student achievement in all cadres by type of course. This multiple comparisons procedure controls for familywise error, permits very different group sizes, and does not require equality of population variances. Alpha was set at .05 for significance. **Not only were significantly greater gains observed for Cadre I students compared to Cadre II and Cadre III students, but even with regard to types of courses where Cadre I students began the year with significantly lower mean pre-test scores, their mean post-test scores were significantly greater than in Cadres II and III for all except Honors Chemistry II.** Cadre I versus Cadre II results are particularly notable.

For example, Cadre I students in regular Chemistry I courses began the year with significantly lower mean pre-test scores than their peers in other cadres, yet they made roughly twice the gains and finished their courses with significantly higher post-test scores. On the pre-test, the 815 Cadre I students in regular Chemistry I courses answered, on average, 21.7% of the ACS items correctly (SD = 10.9%); the 1355 Cadre II students answered 25.8% correctly (SD = 8.1%). Yet post-test mean scores were 36.7% in Cadre I (SD = 12.4%) and 30.5% in Cadre II (SD = 8.5%). Mean pre-test scores for Chemistry I Honors students were not much different in magnitude in Cadre I (mean = 28.7%; SD = 7.9%; n = 207) than in Cadre II (mean = 27.7%; SD = 7.1%; n = 67). But the post-test mean was substantially greater in Cadre I (mean = 45.9%; SD = 12.95%) than in Cadre II (mean = 36.1%; SD = 7.9%). Taking into account both type of course and cadre, gains were greatest for AP classes taught by Cadre I teachers. Those 23 Cadre I students' mean scores at pre-test and post-test, respectively, were 57.4% (SD = 9.9%) and 79.5% (SD = 12.9%), which is quite remarkable.

Concluding Comments

Cadre I teachers have been one year ahead of Cadre II teachers in terms of the professional development they have received, and that has been reflected in their self-reported use of computational science tools and in observed changes in mean scores on the American Chemical Society teacher exam, thereby providing evidence that the ICLCS intervention does, indeed, affect the areas targeted for professional development. As hypothesized, each year mean student gains on the ACS exam have been greater for Cadre I. Moreover, in the most recent academic year (2009 – 2010) not only did Cadre I students always experience significantly greater gains than their counterparts in Cadre II (and Cadre III), but even with regard to types of courses in which Cadre I students began with significantly lower pre-test scores, Cadre I post-test scores were significantly greater than that of their Cadre II counterparts.

These results provide evidence that ICLCS is a powerful intervention that increases rural chemistry teachers' content knowledge, pedagogical skills, and use of computational science tools in the classroom and that these changes are associated with greater student performance on the ACS assessment.

Cadre III teachers' progress may follow a steeper trajectory, partly because the ICLCS intervention has been honed over time, but also because their baseline data show that compared to their predecessors their initial levels of computer literacy tends to be higher and more of them are beginning intervention with more chemistry content knowledge. The finding that 22.2% of them answered 90% or more ACS items correctly is close to results not observed in Cadres I or II until each had experienced a year of ICLCS intervention.

In the current and future years, student achievement will continue to be disaggregated by type of course, and we will be able to compare intra- (and inter-) cadre changes over time using a repeated measures analysis of variance or hierarchical linear modeling.

References

Tinker, R. F., and Xie, Q. (2008). Applying computational science to education: The Molecular Workbench Paradigm. *Computing in Science and Eng*. vol. 10, no. 5, pp. 24 – 27.

Prince, M. (2004). Comparison of student learning in physical and simulated unit operations experiments. *J. Eng. Education.* vol. 93, no. 3, pp. 223 – 231.