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HANDS-ON-SCIENCE: HANDS-ON, INTEGRATED NATURAL SCIENCES FOR PRE-SERVICE ELEMENTARY TEACHERS

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ABSTRACT

How do we teach science to future elementary teachers, while simultaneously giving them the tools they need to engage their own students? The Hands-on-Science (HoS) program at The University of Texas at Austin (UT) is a four-semester, integrated science curriculum designed to train future elementary teachers through the process of guided inquiry, while emphasizing evidence-based reasoning. Students experience phenomena through observation and experiment, and learn to explain and articulate their ideas based on the collected experimental data. HoS develops core concept knowledge across the Natural Sciences in physics, chemistry, geology, biology, astronomy, and Earth science. Our courses are modeled after the groundbreaking work by Fred Goldberg et al. (*Physics and Everyday Thinking,* Goldberg 2008) and the classroom style of the Western Washington University group. We extend these models further, adding geology, biology, astronomy, and Earth science to the subjects addressed. In this paper, we present the framework of a typical lesson and assessment results on both conceptual understanding and attitudinal shifts for students in the HoS program and appropriate comparison groups. We show that HoS students outperform their counterparts in traditional courses in terms of relevant content knowledge gains, increasing their scores by up to three times more than students in traditional courses. Additionally, after participation in the HoS program, students show improved attitudes toward science, including lower anxiety, higher confidence in their own abilities, increased enjoyment of science, and they consider science more relevant to their daily lives. These attitudinal shifts are especially important for future teachers, whose attitudes toward science will impact their teaching and the perceptions of their students. Taken together, these positive changes in student attitudes and content knowledge support the development of pre-service teacher preparation programs like Hands-on-Science.
Keywords: pre-service teachers, attitudes, learning gains

1. INTRODUCTION

The National Commission on Teaching & America's Future (1996) identifies four serious limitations to pre-service elementary teachers' career preparation: inadequate time to learn content, fragmentation of content areas and best practices for teaching in those areas, uninspired teaching methods, and superficial curriculum. Prior to 2009, students preparing for careers in elementary education at UT were required to take any four introductory science courses through the College of Natural Sciences as part of their degree plan. While standard, introductory science classes offer to teach students a wide range of topics within any given field, many science curricula are arguably superficial and have been criticized as being "a mile wide and an inch deep" (Schmidt et al. 1997). Many college students demonstrate deep-seated misunderstandings about basic scientific ideas in fields such as astronomy, physics, and biology to name a few (e.g. Schneps & Sadler 1989). In fact, Lightman & Sadler (1993) show that while teachers in traditional classes can generally predict students' average incoming performance on astronomy assessments, for example, they grossly over-predict the gains in student knowledge of basic astronomy concepts at the end of traditional courses. In addition to the broad content, traditional lecture classes represent a fragmented curriculum offered through different departments, often disconnected from one another. Yet, for students to attain deep understanding of these fundamental scientific principles, explicit connections between content areas and applications are necessary (e.g. Larkin et al. 1980; Gick & Holyoak 1980; Perfetto et al. 1983). Finally, large lecture classes are isolating environments where even involved students are constrained in their ability to engage with the instructor by many factors, such as physical distance, the number of students, and the impersonal environment (Geski 1992). For pre-service teachers, who tend to lack confidence in their own knowledge of science (Young & Kellogg 1993; Ginns & Foster 1983; Riggs 1991), such an environment is, at best, not suited to adequately prepare them to be successful science teachers. For these many reasons, large, broad classes are not necessarily the most useful way to prepare pre-service elementary teachers to understand fundamental scientific concepts and how scientific principles are related across disciplines. These factors conspire to severely negatively impact their self-confidence in understanding and teaching science (Bandura 1993).

In this paper, we outline the design and development of the Hands-on-Science Program and our two data sets for subsequent program evaluation. In Section 2, we describe the HoS program in detail, including the lesson structure, classroom environment, and curriculum. In Section 3, we present the analysis and results on the effectiveness of the HoS curriculum on students' attitudinal shifts toward science. In Section 4, we describe our evaluation and results of students' con-

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Figure 1. Panorama of one Hands-on-Science, studio-style classroom, located in Room 7.114 in the Robert Lee Moore building at UT. Notice the groups of students participating in a student-led discussion. The instructor is seated at bottom right, interjecting and clarifying questions as necessary.

ceptual understanding, using data from HoS and comparison courses. Section 5 summarizes our results and conclusions.

2. COURSE DESIGN

If we are to address the problems in STEM education in the U.S, more effective preparation of pre-service elementary teachers is crucial. To better serve these future elementary teachers, the College of Natural Sciences at UT Austin, in conjunction with UTeach Primary, now offers a four-course science sequence for education majors called Hands-on-Science (HoS), which is specifically tailored to the unique needs of this student population. This four-course sequence is required for all elementary education majors, and serves over 350 students per semester. The HoS program differs from traditional, introductory science classes in two main ways - through teaching methodology and through curriculum.

The HoS program is designed to be a melting pot of best practices for learning in general, and science in particular. Student understanding and the ability to flexibly use knowledge is increased by many factors, including multiple exposures to key ideas in many contexts (Bjork & Richardson-Klavhen 1989), explicitly elliciting misconceptions or naive reasoning (e.g. Confrey 1990; Fitzsimmons et al. 1994; Resnick et al. 1989), active-engagement such as hands-on learning and social learning interactions (McDermott 1991; McDermott & Shaffer 1992; Prather et al. 2004). Because students come into any classroom with prior ideas and experience about the world, the constructivist framework of learning suggests that students may require exposure to many opportunities and contexts to fully integrate a concept into their way of thinking (Confrey 1990). Thus, HoS courses provide environments where active learning is promoted in a hands-on, guided-inquiry manner utilizing all of the factors listed above, in addition to providing integrated science content so students get the chance to grapple with fundamental ideas in multiple contexts.

In preparing pre-service teachers, group work can be particularly important, so that students have the chance to practice teaching each other. Grouping students provides them with the opportunity to participate in the social interactions that provide multiple learning benefits (Mazur 1997; Green 2003). In groups, they can draw on the diverse skill sets of students within their groups to solve problems and collect data. These groups also give students the opportunity to air their ideas in a low-risk setting, making it more likely that students will acknowledge their true preconceptions about the topics at hand, and then share their collective thoughts in class-wide discussions. Employing groups within such studio-style classrooms promotes a transition from the traditional instructor as "sage on the stage", to the "guide by your side" (Prather et al. 2004; Fraknoi 2011). Rather than deliverers of information, instructors within studio-style classrooms function as moderators for class discussion, who probe student knowledge and give students helpful nudges in the right direction. Thus, the design of the HoS courses transforms the classroom into a learner-centered environment within a studio-style classroom, one of which is shown in Fig. 1.

The structural framework for a typical HoS class period is based on the format presented in *Physics and Everyday Thinking* (Goldberg 2008) where students are responsible for constructing their own content knowledge using experiments, discussion with peers, and a curriculum consisting of guiding questions. Each lesson begins with a few questions designed to elicit students' preconceptions or naive reasoning on the main topic of the day. Students then share their ideas with the class, so there is collective knowledge of many possible ways of thinking. Then the students perform data-gathering activities during which they are regularly asked to make predictions and connect trends to other concepts they have seen previously. In this way, the students are encouraged to form their own conclusions about the topic at hand, based on the data they have just seen, rather than accepting scientific principles simply by being told. Finally, each lesson ends with thought-provoking questions, which encourage students to use evidence-based reasoning to summarize the main ideas of the lesson and connect them to other contexts. These questions are the basis for in-class discussions, where students are responsible for presenting their ideas to the class and justifying and elaborating them for their peers. In addition to these methods of in-class instruction, students in the HoS program are tested for their understanding and ability to explain situations using scientific concepts. Since it is difficult to encourage higher-level thinking with multiple-choice tests based largely on declarative knowledge (Stanger-Hall 2012), we format our summative assessments utilizing constructed-response questions requiring several sentences of explanation. These exams form the bulk of students' grades and emphasize that we value explanatory power over memorized, disconnected facts.

Besides the learner-centered classroom dynamic and course design, the other major difference between traditional, introductory courses and HoS is the curriculum itself. In addition to modeling best teaching practices, the HoS program is an integrated science curriculum spanning four semesters. Within these four semesters, the curriculum regularly links concepts across scientific disciplines to emphasize core principles that underlie many applications. For example, the HoS curriculum uses the idea of energy transfer as a unifying scientific concept, which underlies common physics principles such as conservation of energy, but is also used to explain earthquakes, photosynthesis, and seasons. Such integrated science concepts are referenced within the HoS curriculum with common terminology and familiar representations throughout all four semesters. While each semester is meant to tie across disciplines and incorporate integrated science content, the content focus in each of the four semesters is broadly organized in the following sequence: Semester 1: Physics, Semester 2: Chemistry and Geology, Semester 3: Biological Systems, Semester 4: Astronomy and Earth Science.

The HoS curriculum is a standards-based curriculum designed to focus on the concepts that these pre-service teachers will be responsible for teaching in their own classrooms. Researchers have found that a large number of in-service elementary school teachers have many of the same misconceptions as their students (Atwood & Atwood 1996, 1997; Mant & Summers 1993). For pre-service elementary teachers to be effective when introducing their students to these topics, they need explicit instruction on these scientific concepts as part of their preparation. The broad topics we cover in the HoS curriculum are specifically selected to give the students a college-level, deep understanding of underlying concepts represented in the TEKS for grades K-8, with focus on K-5. Giving pre-service teachers a firm understanding of these topics now will hopefully enable them to teach such topics well and with confidence in the future.

3. ATTITUDINAL SURVEY AND RESULTS

Many authors agree on the importance of preparing pre-service elementary school teachers in such a way that they can retain the enjoyment and excitement of scientific discovery while teaching their students (Young & Kellogg 1993; Ginns & Foster 1983; Riggs 1991). As pointed out in Allen (2006), elementary teachers face multiple issues when confronted with teaching science: "They don't like science, they don't feel confident in the knowledge of science, and they don't know how to teach science effectively." To counteract these issues, we must do two things: prepare pre-service elementary teachers with deep understanding of science content, so that they feel confident of their scientific knowledge and the importance of science, and allow pre-service teachers to experience a methodologically-sound approach to teaching and learning science, so that they feel prepared to teach science effectively themselves. HoS is designed to meet both of these goals, and in this section we evaluate our program's effects on measures of student confidence and enjoyment of science.

3.1. *Methodology*

To probe student attitudes toward science, we administer surveys in a pre-test/post-test, two-group, quasi-experimental design. The first group is composed of students in the HoS program (the treatment group), and the second group is composed of students in two conventional lecture classes (the control group). The courses included in the control group represent some alternative courses that HoS students could have taken to attain their science credits in the absence of the HoS program. By comparing these two groups, we are testing whether HoS students' attitudes change differently than they would have if they had taken the control courses.

Both groups complete an online, 25-item, Likert-scale survey about their attitudes toward science in general, and learning science in particular. The survey is adapted and expanded from the first homework assignment in *Physics and Everyday Thinking*. While this 25-question survey represents many different ideas students have about learning science, for simplicity we classify the questions into four categories of similar ideas. The first category, *affect*, represents students' enjoyment of science and includes five items, such as "I like science." The second category, *anxiety*, investigates the students' anxiety when confronted with situations related to science and includes eight items where students are asked to rank how worried each situation makes them. An example item is "Walking on campus and thinking about a science course." Items in the third category, *confidence*, look at the students' confidence in their own abilities to solve problems, and include four items like "I have always done well in science." The fourth category, *utility*, represents the students' conceptions of the utility or relevance of science to everyday life with four statements, including "The subject of science is not very relevant to most people." Note that some statements are worded negatively and so students' responses to those statements are inverted so that all statements within a category are scaled to reflect the same attitude levels. For example, within the anxiety category, items are scored such that a high score reflects high anxiety.

We are particularly interested in the HoS student responses within the anxiety and confidence categories, considering the established difficulty that elementary teachers have with high science and math anxiety and low confidence levels in both their own knowledge of science and their self-efficacy in teaching science (Bandura 1993). If HoS students show a reduction in anxiety about science and increased confidence levels, then they are poised to become more effective science teachers than they would have been in the absence of the HoS program.

Our treatment sample includes 217 students from the HoS program who completed the pre-survey at the beginning of their first HoS course, and the post-survey at the end of the next semester in their second HoS course. The data presented here were collected between Fall 2010 and Spring 2012. Traditional introductory science courses represent the alternative that the HoS students would have taken for their science credits in absence of the HoS program, thus we construct our control group from these courses. However, because students are rarely limited to a fixed sequence of traditional introductory courses, we only have data taken over the course of one semester for comparison from such courses. Altogether, the control sample is comprised of three different large introductory chemistry courses and two similar biology courses, and includes 270 students who completed both pre- and post-surveys in their science course during the Spring 2012 semester.

3.2. *Attitude Results*

For each category, we present the average student pre-test and post-test responses for both the treatment group (HoS students) and the control group. These results are compiled in Table 1 and Figure 2, where blue arrows show the change in student responses for the HoS treatment group from pre- to post-test, and red arrows show changes in the control group for the four categories described above. Note that arrows point from the pre-test average to the post-test average. Focusing on the pre-test scores, we do, in fact, see the aforementioned stereotypes of pre-service teachers' attitudes toward science. HoS students start out with a lower affect score and have less initial confidence ($p < 0.01$, where significance is measured using Student's t-test) than the control group, while they share statistically similar starting attitudes with the control group for both utility and anxiety.

Despite the unfavorable starting attitudes of the treatment group, the HoS students show striking changes in their attitudes over the course of two semesters in the HoS program. In all categories, the HoS students show encouraging changes in their attitudes that are statistically different from those of the

Table 1
Results by Attitude Category

Category	Pre_{HoS}	$Post_{HoS}$	$Pre_{Control}$	$Post_{Control}$
Affect	3.22	3.52	3.46	3.33
Anxiety	3.08	2.62	2.96	2.95
Confidence	2.58	2.95	3.05	2.92
Utility	3.64	3.78	3.65	3.51

Note. — Column (1): Attitude Category, Column (2): Average pre-test score on attitude items for HoS treatment group, Column (3): Average post-test score on attitude items for HoS treatment group, Column (4): Average pre-test score on attitude items for control group, Column (5): Average post-test score on attitude items for control group. Note that all items were surveyed using a 1-5 Likert scale.

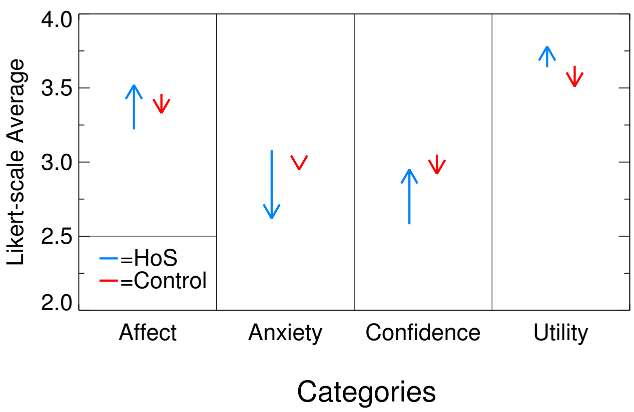

Figure 2. Average student changes in attitudes toward learning science for HoS students (blue arrows) and control students from traditional introductory science courses (red arrows). Arrows point from pre-test averages to post-test averages.

control group ($p < 0.001$). The treatment group's increased affect score shows they enjoy science more, while they decrease in their anxiety toward science, increase their confidence, and consider science to have increased usefulness in their everyday lives. In contrast, the control group shows a decrease in their affective attitudes, no statistically significant change in their anxiety, a decrease in their confidence, and a decrease in the utility of science. Given that the control group represents students in the very courses that HoS students would have taken in the absence of the HoS program, we can say that we have demonstrably improved the preparation experience for these pre-service teachers compared to their previous degree requirements.

This experiment is designed to compare our HoS students to students in traditional science courses, but we acknowledge that these two student populations do not necessarily share the same demographic backgrounds. Most obviously, the gender distributions of the two samples are very different, where HoS students are 95% female and the control group students are more evenly split. Since gender has been tied to science anxiety and confidence (Riggs 1991; Neathery 1997), this difference could bias our results, causing the pre-test scores for HoS students to be offset from students in the control group. Because of this and other possible demographic differences, we are currently investigating the effects of demographics on these student attitudes, but that ongoing investigation lies outside the scope of this paper.

In summary, pre-service teachers in the HoS program have favorable attitude shifts compared to students enrolled in traditional large lecture courses. They show significant increases in affective attitudes, decreased anxiety about science, and increased confidence and utility of science, where students in the traditional courses do not show those trends. From these results, we conclude that the HoS program is meeting one of its two major goals by improving teachers' attitudes toward science, making it more likely that they will enjoy teaching science and feel confident doing it. The other major goal of the program is to improve their content knowledge in the areas that they will teach. We investigate the changes in student content knowledge in Section 4.

4. CONCEPTUAL ASSESSMENT AND RESULTS

Concurrent with data collection for our study of student attitudes, we also investigate quantitative changes in student conceptual knowledge. Because the HoS program incorporates a curriculum and method of teaching that is quite different from the introductory science courses that elementary education majors at UT took prior to 2009, we assess the impact of our inquiry-based, learner-centered classroom style coupled with the focused, integrated HoS curriculum. How do changes in student knowledge in HoS courses compare to those in traditional science classes? Do HoS students, who need specific knowledge and skills for their future careers as teachers, benefit more from the HoS courses than they would have in general science courses?

4.1. *Methodology*

To answer these questions and measure students' content gains, we administer pre- and post-assessments in a quasi-experimental design. The assessments are administered during the first and last week of the semester to both HoS classes and students in traditional introductory science classes. We utilize content assessments from the MOSART (Misconceptions-Oriented Standards-based Assessment Resources for Teachers) group, which are field-tested, accredited assessment tools made up of multiple-choice items[1]. The MOSART assessments are designed to include questions of varying difficulty levels, with attractive, research-based distractors, which allow us to probe for student misconceptions. Questions of varying difficulty levels allow for finer resolution when determining student achievement. The MOSART group makes tests available for grades K–4, 5–8, and 9–12 in physical science, Earth science, and astronomy, and grades K–4 and 5–8 in life science. These assessments are based on the National Science Education Standards (National Research Council 1996) for the appropriate grade levels. In our research, we utilize the six assessments designed for grades K–4 and 5–8 for physical science, Earth science, and astronomy. These grade levels are chosen to be assessed since they contain the concepts that HoS pre-service teachers will be responsible for teaching to their own students. At the time of data collection, the MOSART life sciences assessments were unavailable, so to assess student changes in biology content, we also incorporate additional assessment items from past, grade 5 for science TAKS (Texas Assessment of Knowledge and Skills) tests. We are in the midst of ongoing data collection using the recently released MOSART life science assess-

[1] http://www.cfa.harvard.edu/smgphp/mosart/index.html

ments for grades K–4 and 5–8. The outcome of this research will be reported in a future paper.

As with all course development, we find that we simply cannot cover everything. Because our aim in this study is to determine whether these students are better-served by having access to a program like HoS, we compare data sets for the subset of questions that we do address. HoS instructors independently selected questions from the six MOSART tests (plus additional TAKS questions for biology) that are represented in the HoS curriculum, and we use only those questions where all instructors agree that the content is covered in HoS. Despite the many reasons for using the MOSART questions as our assessment tool (see above), each of the assessments includes a variety of questions that are not addressed, directly or indirectly, in our curriculum. The HoS curriculum emphasizes concepts drawn from national and state science standards (NSES and TEKS) that we consider to be the most fundamental or most difficult for pre-service elementary teachers to go on to teach. For instance, we choose not to assess MOSART questions designed for grade levels 6-8, since these are not directly relevant to the content our future teachers will be responsible for teaching. Additionally, those questions not addressed reflect content that we feel is either too detailed to devote proper time to, or that HoS students will be able to learn for themselves given the skills and background they acquire in the HoS program. Consequently, our assessments include 15 questions for physics, 5 for chemistry, 11 for geology, 26 for biology, and 29 for astronomy.

In order to evaluate HoS students' performance in the context of relevant control groups, it is necessary for us to rely on the generosity of multiple instructors at UT Austin who are not associated with the HoS program. To avoid unnecessary class interference in these instructors' classes, we design our testing methodology to minimize the class time required and reduce the amount of paper necessary for testing. To maintain consistency, the same testing methodology is implemented in our HoS classes. Each student is provided with a scantron to record his/her responses, and presented the assessment questions in a slideshow presentation. Depending on the length of the question, students in each group are given between 30–90 seconds to record their answer. Despite this seemingly short amount of time, the administrants wait for students to finish answering before moving on. At the end of the assessment, students are given the option to return to any questions that they wish to see again.

For each content area, we have a HoS treatment group and a corresponding control group from an appropriate traditional introductory science course, with the exception of geology, where our collection of control group data is currently ongoing and will be reported in a future paper. Our analysis only includes students for whom we have paired pre-test/post-test data. Our sample sizes for each group are reported in Table 2, along with the dates of data collection, and results for each group. Altogether, the treatment sample is comprised of a total of 879 students in the four HoS classes and the control group includes 503 students in appropriate traditional introductory science courses.

4.2. *Content Results*

In Figure 3, we compare the pre- and post-test averages for the HoS treatment group (blue arrows) and the control group (red arrows) for each of the the five content areas. The arrows point from the pre-test average to the post-test average for each sample. We note that, in all categories, the HoS students show significant ($p < 0.001$) increases to their content knowledge after one semester of treatment. In contrast, the control groups show smaller or no gains during the same time interval for the content included on our assessments.

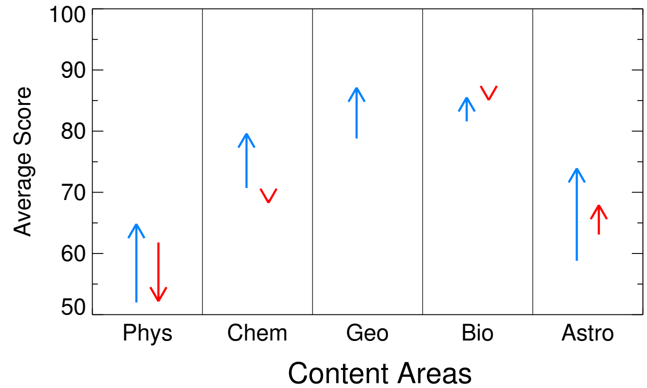

Figure 3. Average student conceptual changes in four scientific disciplines. HoS students are shown as blue arrows and control students from traditional introductory science courses are shown as red arrows. Note that arrows point from pre-test averages to post-test averages.

An additional measure of the change in student performance the is normalized gain $\langle g \rangle$, which is defined as:

$$\langle g \rangle = \frac{\langle Post \rangle - \langle Pre \rangle}{100 - \langle Pre \rangle}$$

Thus, for a single student, g represents the change in the student's score as a fraction of the total possible improvement on that assessment. For example, if a student scores 50 of 100 possible points on the pre-test, he or she has room to improve by 50 points in the post-test. If that student then scores 75 of 100 points on the post-test, then he or she will have a normalized gain, g, of 0.5, meaning that student has increased his or her score by half of the possible amount. For sample averages, we calculate $\langle g \rangle$ as the room for improvement within a sample from the average pre-test score to the average post-test score. Table 2 presents the pre- and post-test averages as well as the $\langle g \rangle$ for each of the two groups and each of the five subjects included in the HoS curriculum.

In physics, the HoS students start from a lower pre-test average than the control group students (52% as compared to 61.8%), but reach a higher post-test average that the control group, obtaining a $\langle g_{\rm HoS} \rangle = 0.27$. Note that the control group has a negative normalized gain after one semester, suggesting that for the items probed in this assessment, the control group students are more likely to answer incorrectly after taking the introductory physics class.

In both chemistry and biology, both the treatment and control groups start from similar pre-test averages of $\sim 70\%$. For chemistry, the HoS students show a significant improvement of almost a letter grade (9.2 points), which corresponds to a $\langle g_{\rm HoS} \rangle = 0.30$. At the same time, the control group shows no improvement. On the biology assessment, HoS students again show improvement ($\langle g_{\rm HoS} \rangle = 0.21$), while the control group students show no significant change.

For the astronomy assessment, both the HoS and the control group students show significant improvement on the content questioned. However, despite a lower pre-test average, the treatment group improves beyond the control group to a higher post-test average. While both sets of students improve, the $\langle g \rangle$ for the HoS students is almost three times higher than that of the control group students ($\langle g_{\rm HoS} \rangle = 0.37$ as compared

Table 2
Sample Information by Content Area

Content Area	N_{HoS}	$Date_{HoS}$	Pre_{HoS}	$Post_{HoS}$	$\langle g\rangle_{HoS}$	$N_{Control}$	$Date_{Control}$	$Pre_{Control}$	$Post_{Control}$	$\langle g\rangle_{Control}$
Physics	337	SP11-SP12	52.0	64.8	0.27	70	F11	61.8	52.2	-0.25
Chemistry	336	SP11-SP12	70.7	79.6	0.30	132	F11	68.8	68.3	-0.02
Geology	336	SP11-SP12	78.8	87.1	0.39	–	–	–	–	–
Biology	118	SP11-F11	81.6	85.5	0.21	191	SP11-F11	85.3	85.1	-0.01
Astronomy	88	SP11-F12	58.8	73.9	0.37	110	F11	63.1	67.9	0.13

Note. — Column (1): Content areas covered in HoS curriculum, Column (2): Number of students in HoS treatment groups, Column (3): Semesters of data collection from HoS students, Column (4): Average pre-test score for HoS treatment groups, Column (5): Average post-test score for HoS treatment groups, Column (6): Normalized gain for HoS treatment groups, Column (7): Number of students in traditional introductory science control groups, Column (8): Semesters of data collection from control students, Column (9): Average pre-test score for control groups, Column (10): Average post-test score for control groups, Column (11): Normalized gain for control groups.

to $\langle g_{\rm Control}\rangle = 0.13$).

Even though no control data is available for comparison for geology, it is still worthy to note that the HoS students attain a $\langle g_{\rm HoS}\rangle = 0.39$ after treatment, even higher than the normalized gains observed in the other four subject categories.

In summary, the treatment group improves on all five content assessments, which specifically test knowledge the HoS students will be responsible to teach, and show higher $\langle g\rangle$ than the control groups for all content areas assessed. Thus, we confidently conclude that the HoS students benefit from higher increases in science content knowledge than they would have in traditional, introductory science courses, and are better prepared for their future careers as elementary school teachers by HoS courses.

5. SUMMARY AND CONCLUSIONS

The Hands-on-Science program at UT Austin sets out to improve pre-service elementary teacher education by providing a coherent, misconceptions-oriented, standards-based, integrated science curriculum, focused on the concepts those teachers will be responsible for teaching in their future careers, and presents that curriculum using best practices of teaching methodology, therefore modeling the teaching styles those teachers will go on to use. The curriculum focuses on conceptual understanding in the areas of physics, chemistry, geology, biology, and astronomy. Because many educators teach in the same manner that they are taught, it is important to educate future teachers using methodology that will encourage best practices in their own classrooms. To gain meaningful understanding of this body of scientific knowledge, students are asked to examine their prior knowledge, perform hands-on experiments to validate their ideas, and draw conclusions using evidence-based reasoning, in small groups and large classroom discussions. Students are then assessed on their ability to explain their ideas and understanding of scientific concepts using evidence they observe in class. The two key goals behind the design of the program are that students learn relevant science and learn it well, and that they also gain increased confidence in their own abilities to understand and explain what they know about scientific concepts.

To test our performance with respect to these goals, we evaluate our program using pre-test/post-test, quasi-experimental data, investigating both attitudinal and conceptual shifts. First, we analyze the attitudinal shifts of students in the HoS program compared to students in traditional introductory courses covering the same scientific disciplines. The students in the HoS program show improved attitudes in all areas, including higher confidence, lower anxiety, greater enjoyment of science, and consider science to be more useful in their daily lives. The students in traditional introductory courses experience either no change or more negative attitudes. We conclude that programs like HoS can meaningfully change pre-service teachers' attitudes toward science, empowering them to become better teachers of science.

To monitor changes in students' conceptual understanding of science, we analyze learning gains on content assessments that utilize questions from the MOSART group (plus additional TAKS questions for biology), categorized by content area. These assessments focus on science content from grades K-8, so we are assessing students' understanding of concepts they will be responsible to teach to their own students. HoS students show improvement in all five content areas. Additionally, compared to control courses that represent the alternative classes these pre-service teachers could have taken for their science credits, HoS students outperform control group students on the overall content in all four content areas compared, by up to three times as much. This indicates that for any number of possible reasons, including more time-on-task, increased student participation and discussion, elicitation of pre-conceptions, or emphasis of evidence-based reasoning, the HoS curriculum and methodology increases the learning gains in the student population served. These results illustrate the success of the HoS program and confirm that these pre-service elementary teachers are better-prepared to teach K-5 science than they would have been in traditional introductory science courses. This success further indicates the importance of learner-centered environments, by showing that courses designed for particular student populations are capable of achieving meaningful increases in student learning in relevant topic areas, as opposed to large, indiscriminate courses, where it is hard to effectively serve many populations of students with different goals.

Among other benefits, encouraging students to think scientifically and promoting their enthusiasm for science will increase the chances of students choosing careers in science or supporting scientific research. Future workers need to be adequately prepared to enter burgeoning technical fields. These workers typically come from college majors in various STEM fields. The U.S. Department of Labor suggests that preparing future workers to enter STEM fields can have long-term effects on the standard of living in the U.S. and employment opportunities for several decades (Jobs for the Future 2007). The National Research Council suggests that a major factor in preparing students for STEM fields lies in "improving K-12 science and mathematics education" (Rising Above the Gathering Storm Committee 2010).

By eighth grade, students are making enrollment decisions that determine their effective ability to participate in a STEM major in college (Akos et al. 2007). Therefore, we need to focus on improving science and mathematics education well before high school. While young elementary school students report that science is valuable and understandable, at some point in grades 4-8, many students loose their enthusiasm (Neathery 1997). Yet it is this very enthusiasm and interest in science that is vital to increasing the number of students who go on to careers in STEM fields (Business-Higher Education Forum 2010). In light of these many factors, it is important to prepare pre-service elementary school teachers in such a way that they can retain the enjoyment and excitement of scientific discovery while teaching their students.

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