Impact of Newton’s Universe Materials on Middle School Teacher and Student Understanding of Physical Science

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Abstract

A unique model of professional development delivered by distance learning and utilizing hands-on inquiry based instruction was developed with the intent of increasing rural middle school teacher and student physical science content knowledge. This program, entitled Newton’s Universe (NU) provided participants (course) with professional development during the summer and a classroom materials kit to utilize when teaching temperature and heat concepts during the school year. Compared to control teachers who did not receive the professional development or classroom materials and their respective students, course teachers and students showed significant gains in their understanding of temperature and heat concepts. However, it remains unclear if the PD provided by NU, the availability of classroom materials, or both were responsible for these gains in content knowledge. In this study, an additional set of teachers (kit) were recruited and provided with classroom materials and no professional development. While kit and control teachers’ understanding of temperature and heat concepts were similar, kit students outperformed control students on the NU assessment. These results suggest the NU classroom materials kit may play a role in increasing student performance.
Introduction

Data from the 1996 and 2005 National Assessment of Educational Progress (NAEP) indicate little change in middle school student achievement in science. The percentage of eight grade students achieving at or above the proficient level in science remained at 32% from 1996 to 2005 (Grigg, Lauko, and Brockway 2006). One possible explanation for the lack of improvement in middle school science is a high frequency of out-of-field teaching. More than half of all teachers teaching physical science classes do not have an academic major or minor in one of the physical sciences (Ingersoll 1999). Even more troubling, many physical science teachers have received no college instruction in the courses they are required to teach (National Center for Education Statistics 2002; Weiss, Banilower, McMahon, and Smith 2001). As teachers are more likely to avoid teaching science concepts they do not understand (Gess-Newsome and Lederman 1995), many middle school students may move onto high school without encountering many physical science concepts that would form the basis for their understanding of upper level physics courses.

A reasonable solution to this problem would be to hire only highly qualified teachers with a deep understanding of the content they teach. Unfortunately, attracting and retaining well qualified science teachers in poor, rural areas is challenging. While almost half (49%) of all United States school districts are located in rural regions, average annual salaries of public school teachers in rural areas are less than teachers in towns, suburbs, and cities (Provasnik et al. 2007). Additionally, rural teachers are more likely to have substandard materials and supplies, as well as inadequate labs and classrooms.
(Lynch 2000). Lack of funding in rural areas can lead to fewer teachers, increasing the frequency of out of field teaching (Collins 1999).

To address this issue, several reform efforts utilize professional development programs aimed at increasing teacher content knowledge, which have been shown to be effective (Darling-Hammond 1998; Garet, Porter, Desimone, Birman, and Yoon 2001). However, implementation of in person professional development programs in rural areas is hindered by lack of teacher participation and inability to access a majority of teachers. One way to overcome the financial and accessibility obstacles inherent in offering in person professional development in rural school districts is by providing high quality, standards based professional development through distance learning. Newton’s Universe (NU) is one such program that provides professional development through distance learning professional combined with inquiry based activities and materials. For a complete description of the NU program, see McNall Krall, Straley, Shafer, and Osborn (2009).

During the summer portion of the NU program, participants receive a materials kit that contains the necessary items for conducting hands-on, inquiry based investigations in a variety of physical science concepts. Discussions and email interaction among participants and with a content knowledge expert aid the teachers in completing the course. In a survey of teachers’ perceptions of the NU course, focusing specifically on components of the course teachers viewed as helpful, 85% reported the materials kit was a major contribution to the effectiveness of the course (McNall Krall, Straley, Shafer, and Osborn 2009).
Following completion of the course, teachers receive the NU classroom materials kit, for use during the school year when teaching physical science concepts. Without separating the influence of the classroom materials kit from the professional development, it is possible that any gains in student understanding are due to the influence of the kit and not due to PD affects on teacher conceptual understanding. Thus, this study examines the impact of the NU classroom materials kit on teacher and student understanding of temperature and heat concepts independent of NU PD.

Methods

Participants

Seventeen middle school physical science teachers were recruited from public schools in rural Kentucky (kit group). These teachers received the NU classroom materials kit but did not receive NU professional development. Prior to this study, NU researchers recruited thirty-nine voluntary middle school physical science teachers (35 course group; 4 control group) from public schools in rural Kentucky and Virginia. During the course of the summer, 13 additional teachers were added to the control group. NU professional development, NU classroom materials kits, and stipends were offered to the course group, while control group teachers received stipends only. As a participant, all teachers and students were asked to complete surveys and assessments on a voluntary and confidential basis.

Data Collection & Analysis

Course and control group teacher assessments were administered in the summer of 2006 by Newton’s Universe. Student data was collected during the 2006-07 academic year from course group students (n=1005) and control group students (n=474). Data from
kit group teachers and students (n=1550) were collected during the 2007-08 academic school year. NU constructed and piloted a teacher assessment and student assessment prior to data collection. All responses were catalogued by random identification numbers and stored in a secure file. Minitab 15 was used as the analysis software. Descriptive and inferential statistics were used to analyze baseline, post, and retention assessment responses. Analysis of variance (ANOVA) with Tukey’s post-hoc test was used to test for statistically significant differences at the .05 level between group means.

Teacher & Student Assessment Instrumentation

All teachers were given a 25 question, multiple-choice assessment developed to measure understanding of temperature and heat (Bradley and Sampson 2006). Teachers took the baseline assessment during the beginning of the summer, the post assessment prior to the start of the academic year, and the retention assessment at the end of the school year. Baseline, post, and retention assessments consisted of identical items.

All students were given a 39 question, multiple-choice assessment developed to measure understanding of temperature and heat. The assessment covered five temperature and heat topics (foundations, properties of matter, energy transfer and transformations, phase change, and thermal energy). Students that had incorrect or missing identification numbers, as well as students that attempted fewer than 20% of the questions, were excluded from analysis. Students took the baseline assessment at the beginning of the academic year, the post assessment immediately following the temperature and heat unit, and the retention assessment at the end of the academic year. Baseline, post, and retention assessments consisted of the identical items.
Results

In order to determine the impact of the NU classroom materials kit, separate from NU professional development, this study compared the scores of students whose teachers received the NU kit and no PD (kit group), the NU kit and PD (course group), and neither the NU kit nor PD (control group). All scores are mean number of questions correct on assessment ± SEM.

Table 1 details descriptive statistics for course, control, and kit group teacher performance on the NU baseline, post, and retention assessment. There is a clear and significant increase in teacher performance for the course group from baseline (13.31 ± 0.647) to post (17.70 ± 0.567) and retention assessments (17.30 ± 0.653) (p<0.05). Control and kit teachers’ scores did not change from baseline to post or from post to retention (p>0.05) (Figure 1).

Table 2 details descriptive statistics for course, control, and kit group student performance on the NU baseline, post, and retention assessment, respectively. Student scores on the baseline assessment were similar in the control (14.29 ± 0.183) and course (14.29 ± 0.125) groups (p>0.05). Kit group student scores (13.27 ± 0.100) were lower than control and course group students (p<0.05). Figure 2 shows a significant increase in scores from baseline to post assessment for control (16.25 ± 0.264), course (17.71 ± 0.192), and kit (16.73 ± 0.151) groups (p<0.05). A subsequent decrease in scores occurs from post to retention assessment in control (15.29 ± 0.248) and kit (16.14 ± 0.171) groups (p<0.05). Contrary to control and kit group results, course group student scores increased from post to retention (18.40 ± 0.259) (p<0.05).
While all groups increased from baseline to post assessment, course group student post assessment scores were significantly higher than control and kit group scores ($p<0.05$). Additionally, course group students scored significantly higher on the retention assessment than control and kit group students ($p<0.05$). While scoring significantly lower than course group students on the retention assessment, kit group student retention scores were significantly higher than control group student scores ($p<0.05$) (Figure 2).

**Discussion**

The ultimate goal of the Newton’s Universe professional development project is to increase student achievement in science by enhancing teachers. NU professional development offered via distance learning, combined with an inquiry based classroom materials kit, increases both teacher and student scores. This study examined the impact of the inquiry based classroom materials kit on teacher and student understanding of temperature and heat concepts independent of NU professional development.

The NU professional development increased teacher content knowledge in the course group, leading to a greater level of understanding of the subject matter prior to the start of the school year than the kit or course teachers, neither of which changed scores from baseline to post assessment. While it would not be expected that control and kit teachers’ scores change from baseline to post, due to a lack of intervention over the summer, it is slightly surprising that the process of teaching temperature and heat concepts during the school year did not change control and kit teachers’ understanding of these concepts as gauged by the retention assessment. One possible explanation for the lack of change is that the kit and control teachers taught the subject matter at a depth consistent with their own level of understanding, and thus they did not expand their own
knowledge through teaching. With no motivation to change their instruction from previous years, they likely presented information in a fashion similar to how they had done so in the past. Conversely, course teachers were encouraged during the NU professional development to think deeply on their understanding of the content, correct misconceptions, and improve their overall grasp of the material.

Course students outperformed kit and control students on both the post and retention assessment. This suggests that the increased content knowledge of the course teachers played a role in student performance. This is in line with prior research which has shown that teacher subject matter knowledge, along with knowledge of teaching and learning, teaching experience, certification status, teacher behaviors, and teacher practices can impact student understanding (Darling-Hammond 1999). However, similar to course students, kit students scored higher than control students on the retention assessments taken at the end of the school year, even though kit and control teachers were equivalent in subject matter knowledge. This indicates that the kit itself assisted students in their retention of knowledge over the course of the school year. It is possible that the availability of classroom materials encouraged teachers to change their methods of teaching, incorporating a more inquiry based approach to presenting temperature and heat content. In the future, classroom observations and survey analysis will examine the impact of the kit on teacher presentation of material.

**Educational Significance**

For an accurate depiction of the impacts of the NU distance training, it is essential to independently determine the impact of the NU kit on student learning in middle school physical science. This study found that while teachers in the NU professional
development program and their respective students outperformed control and kit teachers and students on post and retention assessments, students in classrooms that received the NU kit outperformed control students on the retention assessment. These findings should encourage other professional development programs to explore the impact of their training independent of variables potentially sharing an impact on teacher and student learning.
References


Table 1. Teacher scores on baseline, post, and retention assessments. Values are mean ± SEM.

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Post</th>
<th>Retention</th>
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<tbody>
<tr>
<td>Control</td>
<td>16.00 ± 1.42; n=4</td>
<td>12.71 ± 0.657; n=17</td>
<td>14.85 ± 0.596; n=13</td>
</tr>
<tr>
<td>Course</td>
<td>13.31 ± 0.647; n=35</td>
<td>17.70 ± 0.567; n=33</td>
<td>17.30 ± 0.653; n=23</td>
</tr>
<tr>
<td>Kit</td>
<td>12.41 ± 0.840; n=17</td>
<td>13.06 ± 0.909; n=17</td>
<td>13.77 ± 0.885; n=17</td>
</tr>
</tbody>
</table>
Table 2. Student scores on baseline, post, and retention assessments. Values are mean ± SEM.

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Post</th>
<th>Retention</th>
</tr>
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<tbody>
<tr>
<td>Control</td>
<td>14.29 ± 0.183; n=474</td>
<td>16.25 ± 0.264; n=310</td>
<td>15.29 ± 0.248; n=389</td>
</tr>
<tr>
<td>Course</td>
<td>14.29 ± 0.125; n=1005</td>
<td>17.71 ± 0.192; n=860</td>
<td>18.40 ± 0.259; n=554</td>
</tr>
<tr>
<td>Kit</td>
<td>13.27 ± 0.100; n=1550</td>
<td>16.73 ± 0.151; n=1449</td>
<td>16.14 ± 0.171; n=1156</td>
</tr>
</tbody>
</table>
Figure 1. Course, control, and kit teacher performance on baseline, post, and retention assessments. Values are mean number of questions answered correctly on 25 question multiple choice assessment ± SEM. Control and kit teacher scores did not change from baseline to post to retention (p>0.05). Course teacher scores were significantly higher on post and retention assessments than on the baseline assessment (p<0.05). Course teacher post and retention assessment scores were significantly higher than control and kit teacher post and retention scores, respectively (p<0.05).
Figure 2. Course, control, and kit group student scores on baseline, post, and retention assessments. Values are mean number of questions answered correctly on 39 question multiple choice assessment $\pm$ SEM. All groups’ scores significantly increased from baseline to post ($p<0.05$). Course group students scored significantly higher on retention assessment than post assessment ($p<0.05$). Kit and control group students scored significantly less on retention assessment than on post assessment ($p<0.05$). Kit group baseline score was significantly less than course and control baseline scores ($p<0.05$). Course group post assessment score was significantly greater than control and kit post assessment score ($p<0.05$) which were not significantly different from one another ($p>0.05$). Kit group retention score was significantly greater than course group retention score ($p<0.05$).