

AN ANALYSIS OF PRESERVICE ELEMENTARY TEACHERS' ATTEMPTS TO
DETERMINE FACTORS INFLUENCING THE PERIOD OF A SIMPLE PENDULM

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Abstract

Future elementary school educators are often ill-prepared to teach science in their classroom, yet because of state standards many will be required to do so. Teacher educators endeavor to find meaningful topics that will aid these future teachers while teaching science. Classic physics labs, such as the pendulum lab, can serve to act as a measuring tool that assesses the background knowledge of per-service elementary education majors. This investigation hopes to gain insight into these processes through a two day investigation that requires students to use their current abilities to work as a team on an inquiry-based assignment dealing with pendulums. A set of three inquiry questions along with a Confidence Rating Index (CRI) will be given to the students, both as individuals and groups, a total of four times. Students will be required to design a lab where they must decide on which variables will affect the period of a pendulum. Effort has been made to insure that students come to a realization about the importance of good data collecting through their own efforts along with class discussion, not through a straight lecture format.

An Analysis of Preservice Elementary Teachers' Attempts to Determine Factors Influencing the Period of a Simple Pendulum

Elementary teachers in the United States are confronted with many difficult tasks, not the least of which is trying to teach science. Teaching science in a meaningful way is often problematical due to their lack of science background (Dobey & Schafer, 1984; Colburn & Henriques, 2000) and their own fears of the subject (Jasien 1995; Lindgren & Bleicher, 2005).

To address this issue, Teacher's College at Ball State University requires all elementary education majors to take Physical Science for Teachers as one of three required science courses – regardless of their academic specialty. Through the efforts of the PhysTEC project, an American Association of Physics Teachers (AAPT) and National Science Foundation funded project, the course was revised to include more inquiry-type labs. This instructional practice gives these future teachers experience in designing experiments, collecting data, and forming conclusions – all elements of authentic science. Doing so gives students the opportunity to visualize how science can be taught in a fashion that will allow them to “see” science in a more real-world application. Since many of these pre-service teachers have never been in a physics course, and many of them are afraid of science in general, this course offers an approach to learning that may hopefully be transferred into their own classrooms.

LITERATURE REVIEW

Importance of inquiry for science learning and for preservice teachers

According to Standard A in the *National Science Education Standards* (National Research Council, 1996) teachers need to provide a classroom where active learning

takes place through inquiry learning. David L. Haury in his 1993 article, *Teaching Science through Inquiry*, states that Alfred Novak defines inquiry as “the [set] of behaviors involved in the struggle of human beings for reasonable explanations of phenomena about which they are curious” (cited in Jarrett, 1997, p. 3). A classroom where students become curious because of what they are seeing and doing is one where inquiry learning will be successful. One difficulty in accomplishing this goal is that those who become teachers are often not taught in this manner. According to Hoover (1996), “teachers teach as they are taught” (¶ 11) so frustration and failure can often result if these novice teachers are not well-trained in inquiry teaching methods.

In a similar study, Bowen and Roth (2005) designed a task “where they [preservice elementary education teachers] had to design their own investigations, collect data, transform data, and interpret the transformed data” (p. 1066). Their goal, much like the goals set forth in this study, was to “understand the practices preservice teachers enact when asked to conduct an independent investigation in a science methods course” (p. 1066). Roth & Roychoudhury (1993) expressed concerns about how preservice teachers could authentically conduct their own science investigations where clear conclusions could be seen by the students. These two thoughts specifically address the need for more studies that can shed light on how preservice teachers approach science. With greater insight teacher educators might find means to aid those who are unwillingly forced to teach science so they may become promoters instead of inhibitors of science teaching.

Pendulum – a common example of an inquiry task

Pendulums seem to be a popular topic, and with good reason, for the elementary classroom. Pendulums are easy to study, have limited variables to measure and are seen

in many different forms within a student's purview. As such, the pendulum is commonly used in science inquiry investigations in not only physical science classrooms, but also science methods courses. Gauld, in his 2004 article, *Pendulums in The Physics Education Literature: A Bibliography*, references a total number of 83 articles dealing specifically with the teaching of pendulums or laboratory experiments using them. In this bibliography he references a total of 391 articles concerning the "nature and behavior" of pendulums (p. 811).

Historically, pendulums are one of the earliest models for inquiry science. According to Zachos (2004), pendulums have historical meaning in physics. "Galileo's investigation of the pendulum became a foundation for the establishment of what is now considered the scientific approach to investigating phenomena, so the investigation of pendulum periodicity by students today can be a foundation for assessing and developing the fundamental capabilities that are needed for a scientific approach to the investigation of phenomena" (p. 752). Matthews, Gauld, and Stinner (2004) discussed the historical importance of pendulums. From Galileo's "new science" to the importance of the pendulum in Newton's writing of the *Principia*, they state that "the pendulum was at the core of classical mechanics as it developed through the eighteenth, nineteenth and early twentieth centuries" (p. 261). Certainly, students of all ages should appreciate the relevance of the pendulum in the science arena.

Pendulum labs, as a standard inquiry lab done in the elementary classroom, are an excellent means of teaching relationships among variables. Articles such as *Inquiry Strategies for Science and Mathematics Learning: It's just good teaching* (Jarrett, 1997) use a pendulum lab in a middle school setting to demonstrate good inquiry teaching.

Many studies have been done with both preservice teachers and elementary students. According to Donaldson and Odom (2001), elementary students will benefit from these types of labs since “inquiry-based laboratory classrooms actively engage students in developing essential process skills of guided discovery, critical thinking, problem solving, reflection on learning, and assessment of performance” (p. 29). The Donaldson and Odom article demonstrates how the elementary teacher interested in using inquiry labs might design and assess this type of tool. Preservice elementary teachers, having gone through either a science methods course as described in *Reaching the Reluctant Science Teacher* (Colburn & Henriques, 2000) or an introductory physical science course such as the one discussed in this study and the article by Ward (1997), will have the opportunity to see inquiry in action within their schooling with the result of having seen the correct way to perform this type of lab. While Colburn and Henriques stress the importance of using a nature of science approach to teaching preservice teachers how to conduct scientific research, Ward’s article stresses the need for them to pay attention to their environment and uses the Socratic questioning method to aid in this endeavor. She stresses the necessity for teaching the preservice teacher the importance of observation. This study utilizes this concept by setting up four stages of thought and learning designed to move the preservice teacher from independent incorrect thought processes toward building confidence in their group process.

Preconceptions in data analysis

The role of preconceptions in student learning is an important element of constructivist learning theory. It is especially important, and quite possibly problematic, in inquiry investigations. As stated by Bowen and Roth (2005), “designing

investigations, collecting data, transforming data, and interpreting the resulting representations are quintessential scientific practices” (p. 1063), yet no student goes into a work without some natural preconceptions about the results. These preconceptions can color their view of what they are seeing and what the data is telling them. Everyday experiences, physical phenomena that is counterintuitive, and lack of experience are all reasonable examples of natural events in student’s lives that restrict their ability to see data in an open-minded way (Bransford & Donovan, 2005).

Using tools such as the Certainty of Response Index (CRI) (Hasan, Bagayoko, & Kelley, 1999) gives researchers the ability to help identify and quantify preconceptions. Because preconceptions and/or misconceptions can “hamper, unwittingly, the proper acceptance and integration of new knowledge or skills” (p. 294), it is imperative that these preconceptions be addressed during an investigation. In this way, both the students and the instructor have a means to verify specific difficulties and then measure progress.

Science educators must work to change the conceptions of their students, particularly those who have a weak science background. In *How Students Learn*, the authors emphasize that “instruction in any subject matter that does not explicitly address students’ everyday conceptions typically fails to help them refine or replace these conceptions with others that are scientifically more accurate” (Bransford, Brown, & Cocking, 1999, p. 400). Preconceptions in science run deep – they are neither easy to destroy nor simple to abandon. Continued effort, such as seen in this study, will help future teachers have a better grasp of good science with the result that they will be more willing to teach inquiry-based science in their classroom.

RESEARCH QUESTIONS

The instructor for Physical Science for Teachers has, for many years, watched the difficulties of his students as they worked through inquiry-based laboratory investigations. Their preconceptions and poor data collecting decisions and techniques consistently show their lack of science skills. A pendulum investigation was developed to study how both individuals and groups come to understand the relationships between variables and the period of a pendulum. Through the study of these questions, research questions arose and this study developed. The three questions to be answered in this study are:

1. How, if at all, do preconceptions influence a group's data interpretation?
2. How, if at all, does the experimental design limit a group's ability to correctly answer the inquiry questions?
3. Do individual students overcome preconceptions and correctly respond to exam questions given at a later date?

PARTICIPANTS

The participants in this research were 67 prospective elementary teachers (62 female and 5 male) enrolled in one of their three required science courses, PHYCS 101: Physical Science for Teachers. Students in this three-hour credit course met once per week for laboratory sessions, and three times each week in large group lecture. As with this activity, students frequently divided into small groups and performed laboratory investigations during the lecture sessions. During this activity, students were placed into 17 lab groups, with group sizes ranging from 3 to 5 students.

RESEARCH METHODOLOGY

Purpose of study

This study is intended to look at the relationship between data collection procedures and analysis of a classic pendulum lab. The guided inquiry task directed the students to determine the factor(s) that affect the period of a simple pendulum.

Preservice elementary teachers were expected to design their own data collection procedures and analyze both the results and their own feelings of certainty about those results.

Description of the study

The lab occurred over two consecutive lecture sessions, and a total of four types of data were collected. These included pre-lab individual predictions (Appendix A), a pre-lab group prediction (Appendix B), an initial investigation (Appendix C) with findings about the three variables (hence forth called “Round 1”), and a subsequent investigation (hence forth called “Round 2”) performed after an instructor-led classroom discussion. A second copy of the Laboratory Investigation Handout (Appendix C) was handed out at this time. Each of these documents asked students to use the CRI to rate their confidence in their predictions and conclusions on a scale of zero (totally guessed) to five (certain). This was done in order to better gauge the progress of learning and confidence in their answers.

The goals of the activity were to have students first predict results and then design a pendulum lab that would determine if and/or how mass, length, and angular displacement (amplitude) affect the period of a simple pendulum. Individual students were required to record their predictions and their confidence in their answers, without

discussing the lab with anyone else. Students then came together as a group and repeated this step, working together to come to consensus on their predictions and their confidence levels.

The laboratory initial investigations handout was distributed and students were required to design their own lab including all necessary drawings and tables. Supplies provided to them included masses, string, protractors and stopwatches. Some general definitions were given along with specific questions such as “How, if at all, does the period of a simple pendulum depend on the mass of the pendulum bob?” which prompted the students toward which variables to measure. Students were given no other clues for help in this stage of the lab, but were instructed that their laboratory report should answer the inquiry questions and contain ample data to support their conclusions. Student groups handed in their results at the conclusion of the class period.

An instructor investigation of the lab reports revealed that each group initially timed only one cycle for all measurements, which led to great variation and uncertainty in measurements. On the second day an in-depth discussion occurred. Concerns about the need for obtaining more accurate results through the practice of repeated cycles being timed and then the total time divided by the number of cycles were addressed.

The need for more reliable data was also addressed in the class discussion. As stated in *Science Teaching Reconsidered* (Committee on Undergraduate Science Education, 1997), “Classes in which students must participate in discussion force them to go beyond merely plugging numbers into formulas or memorizing terms. They must learn to explain in their own words what they are thinking and doing” (Chapter 2: How Teachers Teach: Specific Methods: DISCUSSIONS, ¶. 2). Benefits to this type of

discussion should lead the students toward more meaningful efforts in the subsequent investigation. The instructor illustrated how uncertainty increased in data when there was a lack of good measuring techniques. A pendulum with a length of 24.8 cm, and therefore a period of approximately 1.00 s, was set up in the room. At this time the students were not told the value for the period. He distributed ten stopwatches to students sitting near the front of the class. The pendulum was pulled back and released, and each student timed one cycle. The data was recorded and displayed for all to see, and an average period from all data was calculated. A discussion about the differences in the times and what they meant led to the conclusion about the need for better timing for greater agreement.

In order to demonstrate the value of timing for multiple cycles when attempting to determine the period of the pendulum, the same students were then asked to time the same pendulum for ten cycles. After the times were divided by ten, the data was again recorded and an average obtained. This data was much closer to the true value with a standard deviation of 0.011759 compared to a standard deviation of 0.115162 for the one cycle (Table 1). Significantly important agreement of numbers was also discussed. In the Round 1 lab, many groups believed that a difference of as little as 0.05 (or less) seconds was significantly different, causing an increase in data where none really occurred.

Table 1

Period Comparison for Single and Multiple Cycles

Timer	Period (1 Cycle)	Period (10 cycles)
1	0.99	1.013
2	1.16	0.982
4	0.78	0.990
5	0.87	0.988
6	0.85	1.010
7	0.85	1.008
8	0.88	1.018
9	1.04	1.004
10	0.93	1.006
Average	0.938	1.0024
SD	0.115162	0.011759
SD %	12.27737	1.173053

Students were then directed to reassemble into their laboratory groups and perform measurements a second time (Round 2) in order to answer the same inquiry questions. The students repeated the lab and again rated their confidence in their findings according to the CRI. These results were handed in at the conclusion of the class period.

Finally, an exam was given to individuals with the three findings asked as assessment questions. The assessment questions were asked in the same manner, but

reflected an exam format as shown in Figure 1 below. All students were present for the exam, although two students were absent on the first day of the lab and six different students were absent on the second day. Only two of these eight students did not get all variables correct on the exam, one having missed the first day and the other the second.

- ___ Increasing the amplitude of a simple pendulum will cause its period to significantly ...
a. increase b. decrease c. be unchanged
- ___ Increasing the length of the simple pendulum will cause its period to significantly ...
a. increase b. decrease c. be unchanged
- ___ Increasing the mass of the pendulum bob will cause its period to significantly ...
a. increase b. decrease c. be unchanged

Figure 1: Exam questions related to pendulum activity.

RESULTS

Data collection procedures

Since students were not given specifics about the design of their investigation, several different methods were apparent. The timing of one cycle was universal in Round 1. Other procedural aspects varied by group. For example, nine groups used three timers for each trial and the other eight used only two. Groups also varied in the number of different trials in which they changed the variable in question. While investigating the effects of amplitude changes on the period of the pendulum, eight groups took measurements for three different amplitudes, while six groups measured four, and the remaining three groups measured only two. Similarly, twelve groups measured periods for three different lengths, three groups measured periods for four different lengths, and two groups measured only two different lengths while investigating the effects of length

on the period. In the mass trials, nine groups used three different masses while seven groups used four masses and only one group used two masses.

The effects of the instructor-led discussion related to timing techniques was clearly evident in Round 2. All groups showed evidence that they timed for multiple cycles, which resulted in much less variation among the multiple timers. There was little change, however, in the numbers of timers used in each trial. Three groups used four timers for each trial, seven used three timers, and seven groups used two timers. Groups still varied in the number of different trials in which they changed the variable in question, with only slight improvement shown. While investigating the effects of amplitude changes on the period of the pendulum, ten groups took measurements for three different amplitudes and seven groups measured four. Similarly, thirteen groups measured periods for three different lengths and four groups measured periods for four different lengths. In the mass trials, nine groups used four different masses while eight groups used three masses.

Group predictions

When looking at the initial group predictions, it is evident that most of the students had little prior knowledge of pendulums and the factors that affect their period, despite the popularity of this investigation in k-12 settings. No individual student correctly predicted all the answers and only one group correctly predicted that only length affects the period of a pendulum. This seemed to be only a guess since in both Round 1 and 2 their findings were incorrect and changed between the two labs (Figure 2).

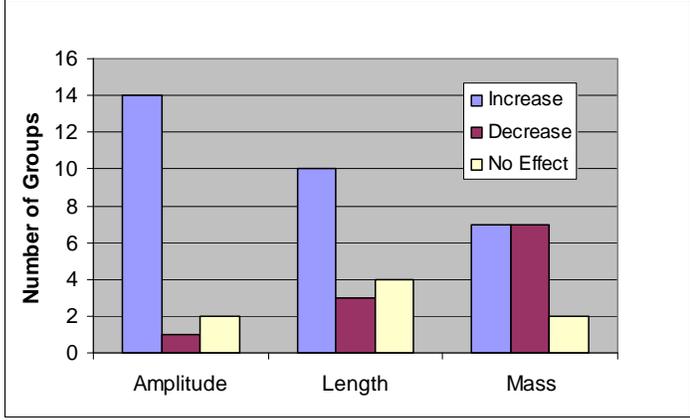


Figure 2. Pendulum results – initial group predictions (n = 17).

Lab results

After the initial investigation (Round 1), 16 groups correctly determined that the period increases with an increase in length, but only 9 groups determined that mass has no effect on the period, and 4 that amplitude has no effect on the period (Figure 3).

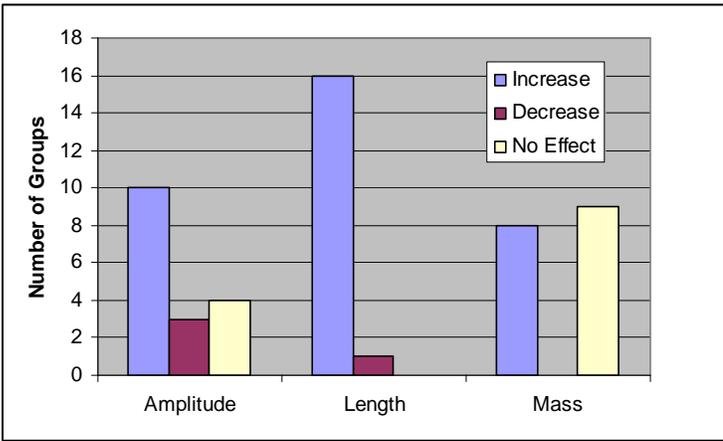


Figure 3. Pendulum results – Round 1 (n = 17).

After the subsequent investigation (Round 2), all seventeen groups correctly determined that the period increases with an increase in length, eight groups determined that mass has no effect on the period, and nine that amplitude has no effect on the period (Figure 4). The other eight groups indicated that the period increases with an increase in amplitude, which is true for “large amplitudes.”

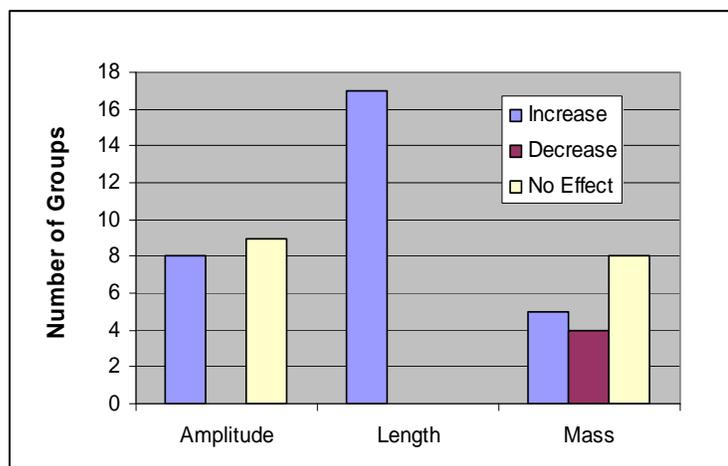


Figure 4. Pendulum results – Round 2 (n = 17).

Overall, four groups reported correct answers to the inquiry questions on both Round 1 and Round 2. Six groups decreased by at least one category in their findings from Round 1 inquiry questions to inquiry questions in Round 2, while four groups improved by at least one category. This leaves three groups with no improvement in their answers.

When considering bias in their answers between their initial group predictions and their answers to the inquiry questions at the end of each lab, five groups held to their original predictions concerning amplitude, even when evidence was to the contrary.

Group 6, for example, concluded on their initial investigation that amplitude increased even though their data was not consistent with that choice (Figure 5).

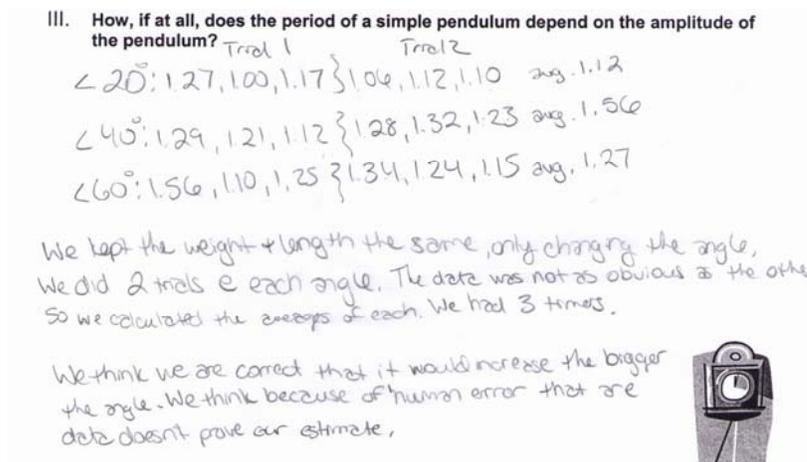


Figure 5. Amplitude results for Group 6: Round 1

Of these five groups that held to their original predictions concerning amplitude, even when evidence was to the contrary, only one group also kept their bias regarding mass affecting the period. A separate group also initially predicted that amplitude was a factor but did change their view on amplitude after the Round 1 lab. Three groups had answers in their lab findings consistent with their reported data after their Round 1 lab, even though the changes in periods were so slight that their significance would be in question. After the class discussion and subsequent lab, these students showed better results in their procedure and answered correctly that mass is not a factor (Figure 6).

III. How, if at all, does the period of a simple pendulum depend on the amplitude of the pendulum?

Degree	W	length	Time 1	Time 2	AVG
70°	106g	50cm	1.19	1.32	1.26
90°	100g	50cm	1.55	1.43	1.47
110°	100g	50cm	2.03	1.61	1.81

The larger the amplitude the longer the period



III. How, if at all, does the period of a simple pendulum depend on the amplitude of the pendulum?

Angle	mass	length	Time	Time	Avg	10 rep
60°	100g	30cm	11.21	11.12	11.165	1.1165
80°	100g	30cm	11.23	10.97	11.05	1.105
40°	100g	30cm	11.21	11.20	11.205	1.1205
90°	100g	30cm	11.74	11.46	11.6	1.16

Undeterminable according to data



Figure 6. Round 1 and 2 amplitude tables for Group 3.

Certainty of Response Index

Initial confidence ratings for individual predictions ranged from two students with zero confidence in all three variables to three students marking a confidence level of five in at least one variable. Initial individual predictions showed average confidence ratings of 2.5 for Amplitude, 2.4 for Length, and 2.3 for Mass. Seven of the groups had initial group (pre-lab) CRI scores of 2 or less for at least two predictions. The average group

confidence levels for initial group (pre-lab) CRI ratings include a 2.8 for Amplitude, a 2.8 for Length and a 3.0 for Mass.

Once the students completed Round 1 they were asked to again rate their group confidence levels in respect to how confident they felt toward the relationship they recorded from their lab. The results showed that there was a confidence level of 4.0 for Amplitude, 4.4 for Length and 3.8 for Mass. Round 2 results show confidence levels of 3.2 for Amplitude, 4.2 for Length, and 3.6 for Mass. Although better measuring techniques were employed, confidence levels actually decreased. See Figure 7 for a summary of all CRI values.

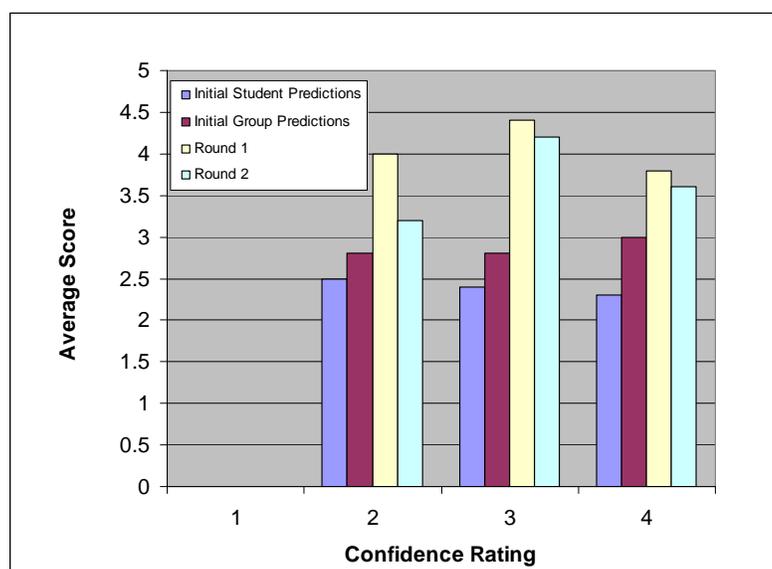


Figure 7. Group confidence levels during two-day investigations

RESPONSE TO RESEARCH QUESTIONS

Research Question 1: How, if at all, do preconceptions influence a group's data interpretation?

Preconceptions did appear to affect students' abilities to discern the significance of slight differences in measured times. Round 1 lab reports revealed that eleven groups attributed significance to differences of less than one-tenth of a second. Of these eleven groups, four groups marked both mass and amplitude as either increasing or decreasing based upon these small differences, while the other seven marked one or the other. Round 2 values showed a decrease to ten groups, with nine of the original groups continuing the pattern. The values for all groups showed an INCREASE in their willingness to attribute significance to smaller differences. One group showed values as small as two thousandth of a second as significant and no group had values closer than five hundredths of a second difference in their data, with most of them being less than that (Figure 8).

1. How, if at all, does the period of a simple pendulum depend on the mass of the pendulum bob?

Length = 50 cm

Amplitude = ~~90~~ 90°

Mass	Time of 10 cycles in seconds	Average Time (s)
500g =	13.68, 14.11, 14.36 = 1.368, 1.411, 1.436 =	1.405
200g =	14.88, 13.61, 14.64 = 1.488, 1.361, 1.464 =	1.438
100g =	15.00, 15.52, 14.95 = 1.500, 1.552, 1.495 =	1.516

As the mass increases, the period decreases.

III. How, if at all, does the period of a simple pendulum depend on the amplitude of the pendulum?

Mass = 100g
Length = 50cm

Amplitude	Time in 10 cycles in secs	Average Time (s)
30 30°	14.22, 15.15, 14.10	1.422, 1.515, 1.410 = 1.449
30 60°	14.63, 15.29, 15.02	1.463, 1.529, 1.502 = 1.498
90°	14.86, 15.53, 14.83	1.486, 1.553, 1.483 = 1.507

As amplitude increased so did the period.



Figure 8. Round 2 amplitude and mass tables for Group 12.

Four groups in the Round 2 investigation stated an increase for either mass or amplitude, yet, with the same small differences in values, stated a finding to be “unchanged” for the other variable (Figure 9).

III. How, if at all, does the period of a simple pendulum depend on the amplitude of the pendulum?

Length = 40° mass = 100g

	Time		Avg
40°	1.245	1.234	1.240
60°	1.287	1.303	1.295
80°	1.288	1.295	1.292

As the Amplitude increases, the time remains fairly constant

We timed 10 trials & divided by 10 to get each time. Then, ~~the~~ Averaged the 2 times.



1. How, if at all, does the period of a simple pendulum depend on the mass of the pendulum bob?

constant ← Amplitude = 50°
length = 50 cm

	Time		Avg
500g	1.234	1.244	1.239
200g	1.378	1.386	1.276
100g	1.415	1.333	1.374
50g	1.420	1.337	1.379

As the mass increases, the time decreases

We timed for 10 periods + divided by 10 to get each time trial + averaged them. We remeasured for each mass, b/c each has different center of gravity.

Figure 9. Amplitude and mass results for Group 7: Round 2

This seems to indicate their unwillingness to change their preconceptions since of the four groups, three continued to mark the same variable incorrect in both labs regardless of what the data showed. Analysis skills are also in question; the students seem at a loss in deciphering what the data is telling them. Evidence for this is seen in their inability to understand that such small changes do not support their views that either mass or amplitude are factors that will change the period of a pendulum.

Research Question 2: How, if at all, does the experimental design limit a group's ability to correctly answer the inquiry questions?

Students had previously performed the traditional inertial balance lab that required multiple oscillations being timed and then the average period found. There was no transference of this lab to the one being discussed, even though the concepts of

oscillations and periodicity were very similar. Other labs had also been performed where students drew tables, ran multiple trials, and averaged their results. Although this investigation offered the opportunity to utilize past experience from previous labs that contained many similar qualities, many groups did not exhibit these traits. The novice learner, as discussed in *How People Learn* (Bransford, Brown, & Cocking, 1999), is one who has difficulty transferring information from one setting to another. “Learners do not always relate the knowledge they possess to new tasks, despite its potential relevance. This ‘disconnect’ has important implications for understanding differences between usable knowledge (which is the kind of knowledge that experts have developed) and less-organized knowledge, which tends to remain ‘inert.’” (p. 237).

In Round 1, the evidence seems to show that students, without prompting or discussion, did not utilize knowledge gained from previous experimentation. The connection between topics is not made so that each lab stands alone with seemingly no relationship between them.

While recording data from the initial investigation, Group5 did not use any form of a table, writing their data in short statements that explained their actions (Figure 10).

III. How, if at all, does the period of a simple pendulum depend on the amplitude of the pendulum?

- We began with a 200g weight
- We pulled the string back 40°
- We had two times of 1.17 sec + 1.00 sec
- We then used a 200g weight again
- We pulled the string back 60°
- We had two times of 1.14s + 1.07 sec
- We concluded that when the amplitude of the pendulum is changed the period is not affected.



Figure 10. Round 1 amplitude results for Group 5.

One group had only one table for all three variables allowing two of the variables to have two measurements (Figure 11), and eight groups organized their data in rows that had little resemblance to a table (Figure 12).

weight	α	string	period	
100g	50°	53 inches	1.32	1.90
100g	90°	53cm	1.38	1.08
200g	50°	53cm	1.40	1.30
200g	90°	53cm	1.37	1.30
100g	50°	78cm	1.96	1.55
100g	90°	78cm	1.71	1.82
500g	50°	53cm	1.43	1.39
500g	50°	78cm	1.53	1.09

Figure 11. Round 1 mass table for Group 4.

I. How, if at all, does the period of a simple pendulum depend on the mass of the pendulum bob?

50g - 1.12s, 1.12s	Yes, the period increases when the mass of the pendulum bob increases.
100g - 1.17s, 1.29s	
200 - 1.16s, 1.33s	
500 - 1.20s, 1.35s	

We timed how long the pendulum took to swing from 50° with two different timers and w/ different masses.

Figure 12. Round 1 Data Table for Group 10.

After the class discussion only two groups showed no improvement in drawing and utilizing tables. An example of a group showing improvement is Group 5, as seen in Figure 13. Their Round 2 table shows an improvement in the methodology that was displayed in Figure 10. Only two groups ran multiple time trials for each lab even though previous labs had demonstrated this aspect of good timing and data collecting.

III. How, if at all, does the period of a simple pendulum depend on the amplitude of the pendulum?

mass	length	amp	period (1)	period (2)
200g	20cm	40°	.967s	.956s
200g	20cm	60°	.971s	.965s
200g	20cm	80°	.981	.953

We still conclude that as the amplitude increased the period is not affected.



Figure 13. Round 1 and 2 amplitude tables for Group 5.

Drawing tables was a component of the lab the students seem to quickly see a need to change. Going from only ten of the groups drawing well-thought out data tables to fifteen doing so shows that students realized this as a better way to report their experimental data and support their conclusions than they had previously done.

Research Question 3: Do individual students overcome preconceptions and correctly respond to exam questions given at a later date?

Exam results versus the inquiry question results in the Round 2 investigation were placed into four categories: students that had both incorrect inquiry results and answers on the exam, student that had incorrect inquiry results but correct answers on the exam, students with correct inquiry results but incorrect answers on exams, and students with correct inquiry results and correct answers on the exam. The group with both incorrect was the largest, with 28 of the 67 students fitting into this category, while the group with both correct was the smallest, with 11 students in the category. What is interesting is that the other two groups, students with incorrect inquiry results but correct answers (15 in this group) and those with correct inquiry results but incorrect exam answers (13 in the group) were very close in agreement and were not much different from the correct in both categories group.

In total, of the 67 students, 26 answered all three exam questions correctly. There were 24 students in the groups that had the correct findings in Round 2, but only 11 of these students had all answers on the exam correct, leaving 13 students with correct inquiry results to end up with incorrect answers on the exam. Forty-one students did not correctly answer all three questions on the exam and there were a total of 43 students that

had incorrect questions on the Round 2, 11 of which eventually answered correctly on the exam (Table 2).

Table 2

Relationship Between Round 2 Group Results and Individual Exam Results

	Number of Students
Total # of Students	67
# of Incorrect Round 2 Questions	43
# of Correct Round 2 Questions	24
# of Incorrect Exam Results	41
# of Correct Exam Results	26
# of Incorrect Round 2 Students w/Incorrect Exam Results	28
# of Incorrect Round 2 Students w/Correct Exam Results	15
# of Correct Round 2 Students w/ Correct Exam Results	11
# of Correct Round 2 Students w/ Incorrect Exam Results	13

Evidence seems to show that reinforcement does work to some extent. All but nine students (58) answered correctly on the exam when concerning length but only 37 gave a correct answer for amplitude while 51 were correct for mass. Student data in labs and reinforcement of that data in lecture led to an amount of confidence that length was indeed a factor. However, even after discussion about timing issues the students did not “buy into” the knowledge that small amounts of change in time did not really indicate a

significant change. It seems that these students have issues with data analysis as much as they do with preconceptions.

Low individual initial CRI ratings seem to have an impact on subsequent thought processes. Three groups showed low CRI scores (2 or less) for all individuals. All students in these three groups had incorrect answers on the exam, although one of the groups had correct answers on Round 2 results. One other group did have correct findings only to have all in the group answer the exam questions incorrectly. This group had an incorrect initial group prediction but correct findings on both labs; CRI values were low on both. This seems to infer that, although students saw the correct data, they did not believe what they saw. Their misconceptions were not replaced by data that proved otherwise and agreed with lecture discussion.

It is worth mentioning that in the initial individual predictions only 30 of the 67 students believed length, the correct variable, to be an influencing factor. On the exam, only seven students incorrectly marked length. Perhaps they were more able to change their view of length since the timing data for length was more straightforward with obvious increases in the timing values. High CRI values of a four or five were given in each of these students' groups. All but three also marked increasing length as a factor as increasing period on their initial individual predictions. Why did these students mark it incorrectly? This would be an interesting topic for further study that could possibly aid in a better understanding of preconceptions students bring with them into the laboratory.

ADDITIONAL FINDINGS

Results from the analysis of Round 2 show that 7 of the 17 groups did not specifically state that they measured multiple cycles to improve their timing data,

although all groups did show less variation in their measurements. Evidence that they did measure multiple cycles of the pendulum is indicated by having measurements recorded to the thousandth place while using stopwatches that only measured to the hundredth place (Figure 14). This leads to the conclusion that although only ten groups specifically stated that they measured multiple cycles, all of the groups did measure multiple cycles, which was a specific requirement in the lab.

II. How, if at all, does the period of a simple pendulum depend on the length of the pendulum?

Mass = 200g Amplitude = 70°	Length	Time for Ten Periods			Avg 10 per	1 Period
		Person 1	Person 2	Person 3		
	20cm	8.28	8.42	8.68	8.53	.853
	40cm	12.67	12.87	12.83	12.79	1.279
	60cm	15.59	15.44	15.62	15.55	1.555
	80cm	18.02	18.58	17.83	18.14	1.814

If you increase the length, the period increases.

Figure 14. Round 2 amplitude table for Group 15. Group shows measurements to the thousandth place. Group did not specifically mention multiple cycles.

DISCUSSION/ANALYSIS OF RESULTS

Data Collection Procedures

There is only a slight indication that students considered how to improve their data from the first lab to the second, even after classroom discussion. As previously mentioned, seven of the groups did not specifically mention any change in their timing and only two of these groups increased the number of timers. Four of these groups did, however, increase the number of trials for least one variable in their second lab.

Interestingly, of the eight groups that did multiple oscillations, only one group increased the number of timers and only two increased the number of trials for at least one variable. Some effort was therefore made in at least six groups to change their method of taking data for amplitude or mass while eight improved their timing techniques. There is evidence for some growth but it is apparent that many of the students will need more experience with these types of labs for a true change in their views to occur. Overall there was little change in how the students viewed data. As seen in their exam results, their lack of skills in this area led to an inability to change their perceptions.

Another possible source of data error and misunderstanding could be in the measurement of length. Although students were warned about the need for careful measuring when different masses were placed on the string, it is very likely that some groups did not take care in this step. This would lead to incorrect data with regard to mass, a factor that cannot be discounted since so many groups did not change their view of its affect on period.

Group Predictions and Certainty of Response Index

Group predictions seem to indicate the willingness of individuals to discuss possible choices in a way that led to increased confidence. It appears that either the group dynamic, the classroom discussions, or both, had some impact since only three groups showed no improvement in their scores from Round 1 results to the follow-up.

Confidence in the group dynamic seems to play a role in how the groups predicted. All but six groups showed an increase in confidence ratings in at least one category from the initial individual ratings to the initial group (pre-lab) rating. There is no easy explanation for the six that decreased. None of these groups have a student that

had an initial confidence rating that would stand out as the “vocal” or strong-willed student; moreover, there does not appear to be any pattern between categories since some of the confidences increased.

Of the seventeen groups, eight groups showed an increase in confidence ratings between their initial group predictions to Round 1, although there is no evidence in their findings to promote this. Of those groups, six incorrectly increased their confidence ratings in their answers for amplitude while five incorrectly increased their confidence ratings in their answers for mass. Although three of these groups incorrectly answered the questions, their CRI values increased. In Round 2, only three groups showed an increase in their confidence ratings while the evidence pointed otherwise, and all of these did not have the same problem in their first inquiry questions. In the findings of these groups, six continued to get the incorrect inquiry questions but their confidence ratings decreased.

While confidence continued to increase from the initial individual ratings through the group initial investigation, once the class discussion was held and inconsistencies brought to light, the confidence ratings actually decreased, even with the increase in the correct answers to the inquiry questions. Perhaps this leads to the conclusion that preconceptions are difficult to replace, and while a student may arrive at a correct answer, he or she may not really trust that answer over their long-held preconceptions.

Exam Results

The exam results showed interesting aspects to the dynamics of learning. Although students did a better job in the measurements in Round 2, only 26 students answered all three exam questions correctly on the exam. No more than a tenth of a

second difference in their measured values was seen in any group, yet only 24 of all the students showed correct lab findings, with only 15 of those giving correct answers on the exam. The other 43 students showed no real understanding of data analysis, as seen in their Round 2 findings, although 11 did get correct answers on the exam. Thirty-eight percent did answer the exam questions correctly. Although it appears that students' preconceptions and lack of experience make it difficult to change their opinions, some progress seems to have been made in their learning.

Since eleven students answered the exam questions correctly despite having incorrect Round 2 findings, the question arises as to whether their groups gave the incorrect answers but those specific students knew the correct answer. An interview with these students would have been beneficial and would be an intriguing aspect to later studies.

FOR FURTHER STUDY

Possible future avenues of study might reveal more about the thoughts of students while working together on this lab. This could be done by interviewing students and/or groups about the specifics of their choices. Specific questions such as "What made the group rate a certain level of confidence when all the individuals each had lower CRI ratings?" and "How do you know when two or three numbers are close in value?" would enlighten the researcher into what considerations the students took into account when writing both predictions and CRI values. An interview process involving both individuals and groups would likely shed light on some of the factors that show the inability of students to correctly master this topic.

IMPLICATIONS FOR TEACHING

Those who go into teaching quickly become aware of their own weaknesses in the classroom. The subjects that are enjoyable to teach are often those that are the most comfortable to teach, usually because of the knowledge base of the teacher. Since science is not normally one of those subjects, an elementary teacher must find ways to surmount this difficulty. As seen in this research, it is not easy to overcome past ignorance or prejudice about how science is done. To overcome past misconceptions takes time; therefore, new teachers need training if they are to become experts in teaching science. Some improvement was seen from this study but it also shows that just one science course of this type while in college is probably not enough to make a strong science teacher.

This lack of knowledge does not mean that successful science teaching is doomed in those teachers' classrooms. An atmosphere of wonder and interest can do much to overcome this problem (Ward, 1997). Elementary teachers that utilize inquiry learning into an environment that deals with hands on, minds on science allow their students to see science in action, not just from textbooks (Colburn & Henriques, 2000). In their research of elementary science inquiry teaching, Dobey and Schafer (1984) found that elementary teachers with an "intermediate level of knowledge demonstrated attributes and behaviors conducive to inquiry learning" (p. 49).

CONCLUSIONS

Hands on science that engages the minds of students will only happen in elementary classrooms where teachers are willing to be learners along with their students.

One science class where inquiry learning occurs during their time in college is not enough to ensure an elementary teacher the skills necessary to teach science. Teacher educators need to address these issues by offering their students situations where authentic science skills can be taught. Dobey and Schafer (1984) studied three levels of pre-service elementary teachers, those with no knowledge, intermediate knowledge, and full knowledge. They were concerned about the amount of knowledge an elementary teacher actually needs in order to do a good job at teaching science. Their study showed that “the three groups of teachers did not significantly differ in their teaching behaviors by the IAST, version 2 (the Instrument for the Analysis of Science Teaching)” (p. 47). In the study they stated that “teacher educators should, therefore, realizing that all teachers face these ‘no knowledge’ situations, help prospective teachers acquire a repertoire of strategies for responding when the answer escapes them or is not there” (p. 48).

Confidence comes not just from knowledge but from action – actually performing experiments in the classroom. The concept of life-long learner has no greater meaning than when teachers themselves continue to learn. A teacher that is willing to learn will become a better teacher. “Teaching and learning should be inseparable, in that learning is a criterion and product of effective teaching. In essence, learning is the goal of teaching” (Committee on Undergraduate Science Education, 1997).

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APPENDIX A: Individual Pre-lab Predictions

Pendulum Predictions

A simple pendulum can be constructed by suspending a mass on a light string and allowing it to swing freely after being pulled to the side. The **period** of a simple pendulum is the amount of **time** needed for the pendulum to swing from one side to the other and back – **one complete cycle**.

The pendulum **bob** is the mass that swings on the end of the light string.

The **length** of the pendulum is the distance from the suspension point to the center of mass of the pendulum bob.

The **amplitude**, or **displacement**, of the pendulum is the angular distance the bob is pulled back from the vertical.

- Record what you think would happen to the period of a simple pendulum if each factor is changed.
- Record how certain you are of each prediction as...
 - 0: totally guessed answer,**
 - 1: almost a guess,**
 - 2: not sure,**
 - 3: sure,**
 - 4: almost certain, or**
 - 5: certain.**

I think that **increasing the amplitude** of a simple pendulum (i.e., pulling it back further before release) will cause its period to...

- a. increase (take more time)
- b. decrease (take less time)
- c. be unchanged (take the same time)

Confidence Rating = _____

I think that **increasing the length** of the simple pendulum (i.e., suspending the bob from a longer string) will cause its period to...

- a. increase (take more time)
- b. decrease (take less time)
- c. be unchanged (take the same time)

Confidence Rating = _____

I think that **increasing the mass** of the pendulum bob (i.e., replacing the bob with a more massive one) will cause its period to...

- a. increase (take more time)
- b. decrease (take less time)
- c. be unchanged (take the same time)

Confidence Rating = _____

Pendulum Predictions

A simple pendulum can be constructed by suspending a mass on a light string and allowing it to swing freely after being pulled to the side. The **period** of a simple pendulum is the amount of **time** needed for the pendulum to swing from one side to the other and back – **one complete cycle**.

The pendulum **bob** is the mass that swings on the end of the light string.

The **length** of the pendulum is the distance from the suspension point to the center of mass of the pendulum bob.

The **amplitude**, or **displacement**, of the pendulum is the angular distance the bob is pulled back from the vertical.

- Record what your group thinks would happen to the period of a simple pendulum if each factor is changed.
- Record how certain your group is of each prediction as...
 - 0: totally guessed answer,**
 - 1: almost a guess,**
 - 2: not sure,**
 - 3: sure,**
 - 4: almost certain, or**
 - 5: certain.**

We think that **increasing the amplitude** of a simple pendulum (i.e., pulling it back further before release) will cause its period to...

- d. increase (take more time)
- e. decrease (take less time)
- f. be unchanged (take the same time)

Confidence Rating = _____

We think that **increasing the length** of the simple pendulum (i.e., suspending the bob from a longer string) will cause its period to...

- d. increase (take more time)
- e. decrease (take less time)
- f. be unchanged (take the same time)

Confidence Rating = _____

We think that **increasing the mass** of the pendulum bob (i.e., replacing the bob with a more massive one) will cause its period to...

- d. increase (take more time)
- e. decrease (take less time)
- f. be unchanged (take the same time)

Confidence Rating = _____

What Factors Influence the Period of a Simple Pendulum?

Objective: To determine if/how **mass**, **length**, and **angular displacement (amplitude)** affect the period of a simple pendulum

Materials: light string, meter stick, stopwatch, masses

- Your simple pendulum will consist of a **mass** suspended by light string from a point about which it can freely swing.
- The **length** of the pendulum is the distance from the point of suspension to the **center of gravity of the mass**.
- The **angular displacement**, or **amplitude**, of the pendulum is the angle at which it is pulled back before release.
- You will measure the **period** (the time it takes for the pendulum bob to swing from one side to the other and back again) while individually varying the mass, length, and angular displacement of the pendulum.



Answer each question in the space provided. **Be sure to include a description of your procedures and the data you collected in order to find your answer.** Your data should convincingly support your conclusions.

- I. **How, if at all, does the period of a simple pendulum depend on the **mass** of the pendulum bob?**

II. How, if at all, does the period of a simple pendulum depend on the **length** of the pendulum?

III. How, if at all, does the period of a simple pendulum depend on the **amplitude** of the pendulum?



IV. Given a pendulum of any specified mass, length, and amplitude, what must be done to that particular pendulum to make its period **double**?

Summarize your findings below.

Record how certain your group is of each conclusion as...

- 0: totally guessed answer,**
- 1: almost a guess,**
- 2: not sure,**
- 3: sure,**
- 4: almost certain, or**
- 5: certain.**

Our group found that **increasing the amplitude** of a simple pendulum (i.e., pulling it back further before release) will cause its period to...

- a. increase (take more time)
- b. decrease (take less time)
- c. be unchanged (take the same time)

Confidence Rating = _____

Our group found that **increasing the length** of the simple pendulum (i.e., suspending the bob from a longer string) will cause its period to...

- a. increase (take more time)
- b. decrease (take less time)
- c. be unchanged (take the same time)

Confidence Rating = _____

Our group found that **increasing the mass** of the pendulum bob (i.e., replacing the bob with a more massive one) will cause its period to...

- a. increase (take more time)
- b. decrease (take less time)
- c. be unchanged (take the same time)

Confidence Rating = _____

What are some factors that might limit the certainty of your conclusions?