Analyzing Student Written Communications: the good, the bad, and (maybe) the ugly*

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http://groups.physics.umn.edu/physed/

*Supported in part by Department of Education (FIPSE), NSF, and the University of Minnesota
AGENDA: A Guide for Discussion

1) Writing
   • UMN’s Writing Across the Curriculum
   • Writing and Problem Solving

2) UMN Instructional Framework

3) Lab Reports
   • What is a Physics Lab?
   • What goes in a lab report?
   • Evaluating lab reports

4) Trials and Tribulations
   • What was good?
   • What was bad?
   • What was somewhat ugly?

What do you want to discuss that is not here?
Teaching with Writing

At the University of Minnesota, instructors from across the disciplines are incorporating writing into their courses. Doing so has affirmed the enhancing role that writing activities can play in student learning. It has also allowed faculty and students alike to recognize that language use and text production take place within disciplinary language communities; writing in Law, for instance, looks different, is directed at a different audiences and is produced for a series of different purposes than is writing in Computer Science.
Mission of the Writing Requirement at the University

- Learning to write is a **life-long task** ... refined through an individual’s personal, social, and professional experiences
- Principal means by which all scholars ... **conduct inquiries and communicate their learning**
- Learning to write effectively can be one of the most **intellectually empowering** components of a university education
- University regards the teaching of writing as a **responsibility shared by all departments**

Thus, the University has established a "**writing across the curriculum**" program

Center for Interdisciplinary Studies of Writing
Good writers:

1) practice on a continuing basis, so one of the goals of writing-intensive courses is to offer **ongoing writing practice**

2) are able to write for a variety of audiences; they understand that effective writing depends on context. For this reason, students should **write in many different kinds of courses, to audiences ranging from their peers to senior scholars and scientists**

3) are able to produce a range of different kinds of writing. So the **nature of the writing** done in "writing-intensive" courses should vary considerably

4) Because no one course can meet all these goals, the **collective goal** of all these writing-intensive courses is to **prepare students to communicate effectively in a variety of situations** at the University, in their future employment, and in their roles as citizens
Writing Intensive Coursework

1) Course grade is directly tied to the quality of the student's writing as well as to knowledge of the subject matter, so that students cannot pass the course who do not meet minimal standards of writing competence.

2) Courses requiring a significant amount of writing -- minimally ten to fifteen finished pages beyond informal writing and any in-class examinations. Note that the page guidelines may be met with an assortment of short assignments that add up to the total.

3) Courses in which students are given instruction on the writing aspect of the assignments.

4) Courses in which assignments include at least one for which students are required to revise a draft and resubmit after receiving feedback from the course instructor or graduate teaching assistant. Otherwise, writing assignments may be of various kinds and have various purposes, as appropriate to the discipline.
Procedure for Change

Transformation Process

Paths

Curriculum

Instructional Framework

Barriers

Initial State of Learner

Instructor

Desired Final State of Learner

F. Reif (1986), Phys. Today, 39
Cognitive Apprenticeship Instruction

Learning in the environment of expert practice

Initial State of the Learner

Students have Misconceptions about

A Field of Knowledge

The Process of Learning

The Process of Problem-solving

The Content of Your Field

All combine to make it difficult for students to solve problems

Not the same as “getting a problem right”
Employment

- Problem Solving
- Interpersonal Skills
- Technical Writing
- Management Skills
- Adv. Computer Skills
- Business Principles
- Statistical Concepts
- Knowledge of Physics
- Advanced Mathematics

Survey of Physics Batchelors, 1994-AIP
Teaching Students to Solve Problems

Solving Problems Requires Conceptual Knowledge:

From Situations to Decisions

- Visualize situation
- Determine goal
- Choose applicable physics principles
- Choose relevant information
- Construct a plan
- Arrive at an answer
- Evaluate the solution

Students must be able to communicate these actions in writing

- English
- Organization
- Pictures
Explicit Problem-solving Framework
Used by experts in all fields

**STEP 1**
Recognize the Problem
What's going on?

**STEP 2**
Describe the problem in terms of the field
What does this have to do with ...... ?

**STEP 3**
Plan a solution
How do I get out of this?

**STEP 4**
Execute the plan
Let's get an answer

**STEP 5**
Evaluate the solution
Can this be true?
Calculus-Based Physics
1200 students/term

Majors

Engineering 75%
Physics/Astro 5%
Chemistry 6%
Mathematics 5%
Biology 9%

Male 79%
Had Calculus 80%
Had HS Physics 87%
Expect A 61%
Work 53%
Work more than 10 hrs/wk 25%

Freshman 64%
Sophomores 22%
Juniors 10%
LECTURES

Three hours each week. (200 students)

RECITATION SECTION

One hour each week – solving a problem in 3 person cooperative groups. Peer coaching, TA coaching. (15 students)

LABORATORY

Two hours each week -- same groups solve experimental problems. Same TA. Peer coaching, TA coaching. (15 students) Written lab reports every 2 weeks.

TESTS

Problem-solving quiz & conceptual questions (usually multiple choice) every three weeks.

Course Structure
Problem Solving Laboratories

- Closely integrated with lecture & recitation
- Always context-rich problems
- Emphasize modeling real systems
- Work in Cooperative Groups
- Lab reports are short technical memos

- Each student hands in an individual laboratory report about every two weeks
- Each group member reports on a different problem
- TA assigns each student a problem at the end of each unit
- Student does not knows which problem will be assigned.
- Report is due in 2 days.
Importance of Laboratory Reports

Learning through synthesis of information

- Students write reports to communicate to themselves and their instructor their understanding of:
  - Logical reasoning
  - Physics concepts
  - Data analysis choices
  - What they’ve learned
  - What they’ve not learned

Clear & Concise technical communication

- Necessary for upper level courses in all majors
- Sought-after skills by employers
  - What is the decision
  - Basis for the decision
  - Consequences of the decision
Statement of the Problem

In a complete statement of the problem you are trying to solve, list the equipment you will use and the issues for selecting such equipment.

The problem was to determine the dependence of the time of flight of a projectile on its initial horizontal velocity. We rolled an aluminum ball down a ramp and off the edge of a table starting from rest at two different positions along the ramp. Starting from the greater height the ramp meant the ball had a larger horizontal velocity when it rolled along the table. Since the table was horizontal, that was the horizontal velocity when it entered the air. See Figure 1 from my lab journal for a picture of the set-up.

We made two movies with the video equipment provided, one for a fast rolling ball and one for a slower one. These movies were analyzed with LabVIEW® to study the projectile's motion in the horizontal and vertical directions.

Prediction

Next comes your prediction. Notice the general nature for choosing the prediction is given. In this class there is historical relationship between and . This relationship is not life changing, the acceptance of the trends. Also, make your prediction range, that is in the middle. The prediction does not need to be correct, it must be to what you think likely things may be doing the lab, that is of why it is called a prediction. The predictions proposed to be used as a basis for your group to determine the outcome of the problem.

Our group predicted that the time of flight would be greater if the horizontal velocity was greater. We have observed that a projectile goes further, the longer its trajectory. Since the gravitational acceleration is constant, we assumed that the ball would take more time to travel a larger distance.

Data and Results

This section describes your experimental method, the data that you collected, any problems you encountered, the things you did and the graph and conclusions you made. Your results should show you if your prediction was correct or not.
Conclusions

This section summarizes your results. In the most concise manner possible, it answers the original question of the lab.

Our graph indicates that the time of flight is independent of the ball’s initial horizontal velocity (see lab journal, Graph A). We conclude that there is no relationship between these two quantities.

A good conclusion should compare actual results with the predictions. If your prediction was incorrect, then you must discuss why you were wrong. If your prediction was correct, then you...
Sample laboratory Report

Copies from Laboratory Journal
### Guideline for grading laboratory reports

<table>
<thead>
<tr>
<th>Problem Report:</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ORGANIZATION</strong></td>
<td></td>
</tr>
<tr>
<td>(clear and readable; correct grammar and spelling; section headings provided; <strong>physics stated correctly</strong>)</td>
<td></td>
</tr>
<tr>
<td><strong>DATA AND DATA TABLES</strong></td>
<td></td>
</tr>
<tr>
<td>(clear and readable; units and assigned uncertainties clearly stated)</td>
<td></td>
</tr>
<tr>
<td><strong>RESULTS</strong></td>
<td></td>
</tr>
<tr>
<td>(results clearly indicated; correct, logical, and well-organized calculations with uncertainties indicated; scales, labels and uncertainties on graphs; <strong>physics stated correctly</strong>)</td>
<td></td>
</tr>
<tr>
<td><strong>CONCLUSIONS</strong></td>
<td></td>
</tr>
<tr>
<td>(comparison to prediction &amp; theory discussed with <strong>physics stated correctly</strong>; possible sources of uncertainties identified; attention called to experimental problems)</td>
<td></td>
</tr>
</tbody>
</table>

*Given to TAs & Students in Lab Manual*
General Criteria for evaluating technical Reports
(Dr. Lee-Ann K. Breuch, Dept. Of Rhetoric, U of MN)

• **Content:** What is the subject? What information needs to be included?
• **Context:** What is expected in the discipline for this type of document?
• **Audience:** To whom is the document written? How will it be used?
• **Organization:** How can the information be best organized? Can the information be divided into sections?
• **Support:** What details, facts, and evidence can be used to illustrate main points?
# Example of quality levels - Content

<table>
<thead>
<tr>
<th></th>
<th>Satisfactory</th>
<th>Adequate</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Addresses content accurately and thoroughly</strong></td>
<td>Accurate and complete technical information, including formulas, explanations, theory, and data.</td>
<td>Accurate technical information, but has missed some important information.</td>
<td>Does not include accurate or complete information.</td>
</tr>
<tr>
<td><strong>Score</strong></td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
# Example of quality levels - Context

<table>
<thead>
<tr>
<th>The format is as suitable for a short technical document.</th>
<th>Satisfactory</th>
<th>Adequate</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meets the requirements of the assignment; includes proper format &amp; sections that assignment requires.</td>
<td>Adequately meets requirements of the assignment; does not always display proper format.</td>
<td>Does not meet the requirements of the assignment as specified.</td>
<td></td>
</tr>
<tr>
<td>Score</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
### Example of quality levels - Audience

<table>
<thead>
<tr>
<th></th>
<th>Satisfactory</th>
<th>Adequate</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>The paper can be understood</td>
<td>Writes appropriately for classmates, including proper terms, explanations</td>
<td>Does not always include proper terms, concepts, or register (perhaps is</td>
<td>Does not include proper terms, concepts, or register to effectively</td>
</tr>
<tr>
<td>by classmates in this physics class.</td>
<td>of concepts, formal register.</td>
<td>is too informal).</td>
<td>address audience.</td>
</tr>
<tr>
<td>Score</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
**Example of quality levels - Organization**

<table>
<thead>
<tr>
<th>The paper is logically organized</th>
<th>Satisfactory</th>
<th>Adequate</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Has complete, concise, paragraphs; includes strong topic sentences that indicate focus of paragraph or section; includes strong forecasting statements; includes appropriate headings &amp; subheadings; demonstrates coherence throughout report.</td>
<td>Adequate overall format; does not display concise paragraph or topic sentences; does not have all appropriate headings &amp; subheadings; paragraphs are not clearly coherent.</td>
<td>Does not use appropriate headings or subheading; paragraphs do not logically connect nor are they concise; topic sentences are not effective.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Score</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
</table>
# Example of quality levels - Support

<table>
<thead>
<tr>
<th>The paper has adequate support for statements</th>
<th>Satisfactory</th>
<th>Adequate</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Has necessary illustrations or figures.</td>
<td>Has necessary illustrations or figures.</td>
<td>Has appropriate readings &amp; background information, but does not use clear logic; has tables &amp; graphs but they are not always labeled or cross-referenced.</td>
<td>Does not include necessary support in the form of logic, background information, tables, or graphs. No labeling, &amp; cross-references.</td>
</tr>
<tr>
<td>Refers to appropriate readings, theories, &amp; relevant background information; includes relevant graphs &amp; tables; with proper labeling &amp; cross-references figures, tables, &amp; graphs.</td>
<td>Refers to appropriate readings, theories, &amp; relevant background information; includes relevant graphs &amp; tables; with proper labeling &amp; cross-references figures, tables, &amp; graphs.</td>
<td>Refers to appropriate readings, theories, &amp; relevant background information; includes relevant graphs &amp; tables; with proper labeling &amp; cross-references figures, tables, &amp; graphs.</td>
<td>Refers to appropriate readings, theories, &amp; relevant background information; includes relevant graphs &amp; tables; with proper labeling &amp; cross-references figures, tables, &amp; graphs.</td>
</tr>
<tr>
<td>Score</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
Example – Content & Support

Satisfactory:

• While the beam was rotating we timed how long it took to make five revolutions. We did this to determine the angular velocity, \( w \). Once we knew \( w \) we plugged that value into the equation \( v = Rw \), where \( R \) is the radius. Our group and I concluded that the linear velocity (\( v \)) of a point on the beam increases when the radius increases with a constant angular velocity. There is a graph at the end of the report that shows this relationship for easier understanding.

Poor:

• I observed that the acceleration is zero at the time where the cart switches from going up the track to down the track. This is what we predicted to happen. Our group ... The graph is a constant slope from left to right because the acceleration is always negative and this is why the graph is an upside down parabola. This lab has helped me understand ... The acceleration is always negative (in this respect) which is a little hard to comprehend at first but it was nice to observe this in lab.
A Lab Section

• One class of 15 students
  – 11 of which had all 6 laboratory reports from the entire 15-week semester (n = 11)

• Each student is placed into one of three groups based on the grade of the first report
  – Poor
  – Adequate
  – Satisfactory
Content: What information needs to be included?

Support: What details, facts, and evidence are used?

Topic of paper number:

1) 1-D Kinematics
2) 2-D Kinematics
3) Forces
4) Conservation of Energy and Momentum
5) Rotational Kinematics
6) Rotational Dynamics

Content:

Class (11)
- Poor (4)
- Adequate (7)

Support:

Class (11)
- Poor (8)
- Adequate (2)
- Satisfactory (1)
Context: What is expected for this type of document?

Class (11)
Poor (3)
Adequate (6)
Satisfactory (2)

Audience: To whom is the document written?

Class (11)
Poor (1)
Adequate (7)
Satisfactory (3)

Organization: Is the logic evident in the presentation?

Class (11)
Poor (3)
Adequate (7)
Satisfactory (1)
The “Good”

• Students at all starting levels showed improvement in each of the criteria

  – Except for those students that were initially satisfactory, average rating of each group reached approximately the same quality by the end of the 15-week semester
The “Good”

- Identifiable increases in quality apparent by 3rd or 4th report
  - content, context, audience, & organization

- Slower increases in quality of support
  - majority of students only slightly higher than “adequate”
The “Good”

- Similar increases identifiable in grading by the TA
  - Identifiable correlation between TA grading (rubric) and independent analysis (writing criteria)
Now the questions is …

Does this have any relationship with anything else students are doing in the course?
As teachers, we frequently attempt to measure what students learn, and although this is relatively difficult, it is our belief that somehow it may reflect aspects of student knowledge.

Some ways of measuring student knowledge in our physics courses:

1. **Expository** – *Written Laboratory Reports*
2. **Qualitative (Conceptual)** – *Multiple Choice Questions* (FCI, MBT, etc …)
3. **Quantitative** – *Problem Solving*
So we decided to take an initial look at the 3 measurements together

**Data**

- ~700 Students in 4 lecture sections
- Each section required a number of reports (4 to 8)
- Students are otherwise not significantly different as indicated by the average post FCI results

**Analysis**

- Calculate R of Final MC Score vs. Total Laboratory Report Score
- Calculate R of Final PS Score vs. Total Laboratory Report Score

Both calculations done within each lecture section
What might be expect when comparing final exam scores with written lab report scores?

Besides the machine-graded MC …

Grading on lab reports and exam problems generates significant amount of noise
TAs are given significant guidance in grading:

~ 3 hours for each during orientation and the in-service training

TAs come from a variety of backgrounds and countries ... so despite the training, we can expect different criteria.

In terms of noise:

The TAs that grade the lab reports also grade the exams.

Each exam problem graded by a different person.
Final Multiple Choice vs. Lab Reports

Sec A (N = 186)

% Lab  R = 0.26
6 written lab reports  Post FCI = 70%
Final Probs = 47%  MC = 59%

Sec B (N = 124)

% Lab  R = 0.30
7 written lab reports  Post FCI = 71%
Final Probs = 47%  MC = 50%

Sec C (N = 210)

% Lab  R = 0.21
4 written lab reports  Post FCI = 72%
Final Probs = 52%  MC = 59%

Sec D (N = 180)

% Lab  R = 0.28
8 written lab reports  Post FCI = 71%
Final Probs = 42%  MC = 59%
Final Problems vs. Lab Reports

Sec A (N = 186)

6 written lab reports  Post FCI = 70%
Final Probs = 47%  MC = 59%

% Lab  R = 0.33

Sec B (N = 124)

7 written lab reports  Post FCI = 71%
Final Probs = 47%  MC = 50%

% Lab  R = 0.38

Sec C (N = 210)

4 written lab reports  Post FCI = 72 %
Final Probs = 52 %  MC = 59%

% Lab  R = 0.43

Sec D (N = 180)

8 written lab reports Post FCI = 71 %
Final Probs = 42 %  MC = 59%

% Lab  R = 0.45
<table>
<thead>
<tr>
<th>R</th>
<th>Final MC</th>
<th>Final PS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab Report</td>
<td>0.26</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td>0.21</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td>0.28</td>
<td>0.43</td>
</tr>
<tr>
<td></td>
<td>0.45</td>
<td>0.45</td>
</tr>
</tbody>
</table>
The “Bad”

• Measures on the laboratory reports seems to have some correlation with the other comprehensive measures in the course

– Correlations are, however, not necessarily educationally significant for the most part
So, from this simple-minded analysis, we cannot say whether writing laboratory reports, as we’ve implemented so far, has any effect on student learning as shown by their performances on various other measures in the course
The “Bad”

• As we suspected, the measures are very noisy
  – The effect, if it exists, may be masked by the noises in the measurement
  – More difficult to tease out then can be done using simple measures
The “Bad”

• Despite efforts to somewhat “level the playing field”
  – Format implementations differ between lecture sections
  – Regulation enforcements differ in scope and emphasis

(anecdotal evidence)
We need to do a refined analysis, of problems and lab reports, to attempt to reduce the Noise.

A refined analysis could involve one person evaluating the laboratory reports and problems using carefully followed criteria.
The “somewhat ugly”

Data Collection

• Collection of the data has been painfully gruesome
  – Hard copies of laboratory reports needed to be digitized for archival purposes (~ 2.5 GB)

• TA’s became somewhat troubled by the extra work, without understanding the purposes of the data collection
  – Led to incomplete sets
The “somewhat ugly”

Data Analysis

- We now have collected 300 complete sets of written laboratory reports from introductory physics
  - Each set contains from 4 to 8 reports (depending on the section requirements)
- Matching set of 300 Final Exams
  - Each set contains 5 problems and multiple choice questions
- Matching set of 300 Conceptual Exams
  - Each set contains pre- & post-instruction results
- Matching set of 300 Locus of Control Surveys
The “somewhat ugly”

Implementation

• Having a fast turn-around is important for feedback
  – Fast pace of course makes it difficult for re-writes
  – May be possible to implement a peer review structure, but that also affects the turn-around time
  – So …?
Importance of Laboratory Reports

Learning through synthesis of information

- Students write reports to communicate to themselves and their instructor their understanding of:
  - Logical reasoning
  - Physics concepts
  - Data analysis choices
  - What they’ve learned
  - What they’ve not learned

Clear & Concise technical communication

- Necessary for upper level courses in all majors
- Sought-after skills by employers
  - What is the decision
  - Basis for the decision
  - Consequences of the decision
The End

Please visit our website for more information:

http://groups.physics.umn.edu/physed/

or visit

The Center for Interdisciplinary Studies of Writing at:

http://cisw.cla.umn.edu/
You have a summer job with a research group studying the ecology of a rain forest in South America. To avoid walking on the delicate rain forest floor, the team members walk along a rope walkway that the local inhabitants have strung from tree to tree through the forest canopy. Your supervisor is concerned about the maximum amount of equipment each team member should carry to safely walk from tree to tree. If the walkway sags too much, the team member could be in danger, not to mention possible damage to the rain forest floor. You are assigned to set the load standards.
The Problem

Each end of the rope supporting the walkway goes over a branch and then is attached to a large weight hanging down. You need to determine how the sag of the walkway is related to the mass of a team member plus equipment when they are at the center of the walkway between two trees. To check your calculation, you decide to model the situation using the equipment shown below.

How does the vertical displacement of an object suspended on a string halfway between two branches, depend on the mass of that object?
The system consists of a central object, B, suspended halfway between two pulleys by strings. The picture above is similar to the situation with which you will work. The objects A and C, which have the same mass (m), allow you to determine the force exerted on the central object by the string. You do need to make some assumptions about what you can neglect. For this investigation, you will also need a meter stick and weights to vary the mass of B.
Prediction

Calculate the change in the vertical displacement of the central object (B) as you increase its mass. You should obtain an equation that predicts how the vertical displacement of central object B depends on its mass, the mass of objects A and C, and the horizontal distance between the two pulleys.

Use your equation to make a graph of the vertical displacement of object B as a function of its mass.
Methods Questions
(Coaching Problem Solving)

1. **Draw a sketch** like the one in the Equipment section. Use **trigonometry** to show how the vertical displacement of object B is related to the angle that the string between the two pulleys sags below the horizontal.

2. **Identify** the "known" (measurable) **quantities** (L, m and M) and the unknown quantity (the vertical displacement of object B).

3. **Use Newton's laws.** Write down the acceleration and draw separate **force diagrams** for objects A, B, C and for point P. For each force diagram, write Newton's second law along each **coordinate axis**.

4. **Solve your equations** to predict how the vertical displacement of object B depends on its mass (M), the mass (m) of objects A and C, and the horizontal distance between the two pulleys (L). Use this resulting equation to make a graph of how the vertical displacement changes as a function of the mass of object B.

Appendix p. v
**Exploration**

Start with just the string suspended between the pulleys (no central object), so that the string looks horizontal. Attach a central object and observe how the string sags. **Decide** on the origin from which you will measure the vertical position of the object.

Do the pulleys behave in a frictionless way for the entire range of weights you will use? How can you **determine** if the assumption of frictionless pulleys is a good one?

Add mass to the central object to **decide** what increments of mass will give a good range of values for the measurement. **Decide** how many measurements you will need to make.
**Measurement**

Measure the vertical position of the central object as you increase its mass. Make a table and record your measurements.

**Analysis**

Make a graph of the vertical displacement of the central object as a function of its mass based on your measurements. On the same graph, plot your predicted equation.

Where do the two curves match? Where do the two curves start to diverge from one another? What does this tell you about the system?

What are the limitations on the accuracy of your measurements and analysis?

Appendix p. vii
Conclusion

What will you report to your supervisor? How does the vertical displacement of an object suspended on a string between two pulleys depend on the mass of that object? Did your measurements of the vertical displacement of object B agree with your initial predictions? If not, why? State your result in the most general terms supported by your analysis.

What information would you need to apply your calculation to the walkway through the rain forest?

Estimate reasonable values for the information you need, and solve the problem for the walkway over the rain forest.

Appendix p. viii