Writing to Learn/Learning to Write: An Example from Physics

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Overview

- Learning to Write/Writing to Learn: how did I get here?
- Theories of Writing: WAC & WID
- Writing in an introductory physics course for non-science majors
- Three crucial questions
- What students think while they write
• **Why Writing: Writing in the Disciplines**

  • Hermsen: 2003 Provost’s Learning Innovations Grant to incorporate formal writing into disciplinary classes

  • *Writing in the Disciplines (WID)* and *Writing Across the Curriculum (WAC)* claim that:
    
    * students can master discipline-specific conventions best through assignments in disciplinary courses
    * understanding these conventions leads to an improved understanding of content.

  • If we relate these conventions with epistemologies (what constitutes acceptable proof, logic, etc.) then these claims may be supported by current PER (Hammer, Elby, et al.)
Writing in Physics

• Long lab reports as rite of passage: no formal writing instruction, little assessment

• Leonard & Mullin incorporated writing into introductory and upper level physics courses, cited as model WAC courses. Assessment was anecdotal.

• Joyner & Larkin linked intro physics course with writing course (for motivation). Looked for impact on FCI.

• Etkina et al. studied student epistemologies with written responses to very specific questions. Coded sentence types based on level of sophistication of ideas.
Writing Theories: 1970-2000

• 1970: (Peter Elbow) Expressivist Composition Theory (freewriting)

• 1980: (Lind Flower & John Hayes) Cognitive Theories of Composition
  ∗ writing is a recursive process, requiring revision
  ∗ students need instruction in thinking of writing as process
  ∗ acontextual; leads to “Writing Across the Curriculum” (WAC)

• 1990: (James Berlin, Patricia Bizzell, Victor Vitanza) Social Constructivist Theories of Composition (non-foundational critical consciousness)

• 2000: (Thomas Ken) Paralogic Hermeneutics Theories of Composition (community of practice)
  ∗ reaction to cognitive theories
  ∗ writing too context-dependent to be understood as a “theory”
  ∗ at most train students to respond to discipline-specific prompts
  ∗ leads to “Writing in the Disciplines” (WID)
WAC & WID

• WAC — Art Young, Susan McLead
  ＊ “learn to write” — students learning to write in variety of contexts
  ＊ emphasizes portability of writing across disciplinary lines
  ＊ Writing intensive courses in all disciplines (Science Writing 101; writing is skill to be learned )

• WID — Jonathan Monroe, David Russell
  ＊ “write to learn” — writing instruction as a means of teaching academic specialization
  ＊ learning how to communicate facilitates acquisition of content
  ＊ writing an integral part of the real work and practice of “disciplinarity”, writing assignments and instruction integrated into course
  ＊ writing is a tool to help learn physics
Incorporating Writing in an Introductory Physics Course

- *Explorations in Physics*: activity-based course for non-science majors (information technology, computer science and economics)


- 10 week quarter: 6 weeks on two topics (3 weeks each), 4 weeks on a student directed project.
Writing in EiP, Trial 1: Rubrics

• Students wrote weekly journals
  ∗ describe weekly activities and connect them with bigger picture
  ∗ revise previous entries and integrate revision with new entry into one coherent essay
  ∗ 3 revisions per topic

• provided examples of good/bad writing, grading schema

• asked to write at tone of Scientific American article, interested non-scientist reader

• No explicit writing instruction in class
Sentence Types

- students wrote five types of sentences: Motivation, Procedure, Observation, Inference, and Speculation.

- Each has its place, but the proportions seemed out-of-whack

  This being found, we began to experiment more with buoyant force and its relation to water displaced by an object when it’s dropped in water. By performing several experiments with an overflow can and measuring the amount of water displaced, we were able to conclude that buoyant force on an object and the amount of water displaced by the same object are related to each other, and seemed to be equal to each other. Thus, we began to experiment with the possibility of calculating buoyant force on object simply by measuring its volume and predicting the amount of water it will displace. We created a set standard based on the amount of water displaced by an object of a certain volume, and then used that standard to predict the buoyant force on objects of different volumes.
Students Learn to Play the Game

Motivation
Procedure
Observation
Inference
Speculation

Frequency

A1
A2
B1
B2
- preponderance of procedure-observation sentences

- Lack of inference & speculation, especially in concluding sentences
• more interpretive sentences shows greater attempt to connect ideas

• Speculation often follows inferences
Writing in *EiP*, Trial 2: Rhetorical Discourse Analysis

- papers put into .pdf form, annotations “untainted”
- focused on grammar, style, detail, coherence
- often drawn to same area for different reasons
Local Variations in Student Writing

• Student writing changes appreciably from paragraph to paragraph. Consider the following fragments from successive paragraphs (floating & unbalanced forces):

  However the water can push or force the object up therefore keeping it afloat. Both objects that sink or float have similar forces from both gravity and the water in order to keep them in one position either at the bottom or top of the water. This was shown by the objects that sink staying at the bottom or staying at the top of the water and floating once they had been placed into the water.

  However, then the forces are unbalanced and one force is acting greater then the other the object will begin to move. For example if I push right on a cart then it will begin to move towards the right, or if I pull it from the left it will begin to move to the left, as long as the force that I am pushing or pulling with is greater then the forces acting on it in the opposite direction.
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  Transition sophistication

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  Generalization beyond specific activities
Paragraph Level Variations

- In the next paragraph, the student returns to simplistic writing

- Note lack of transitions, chronological reporting of activities, complete lack of any generalizations

Also in order to measure pressure and buoyant forces we used a force sensor. The force sensor was able to help us determine the amount of buoyant force on and object by initially determining the force in Newtons when the object is suspended from the force sensor in the air, and the force measured in Newton’s when the object is being lowered into the water. The difference between these two forces was the amount (in Newtons) of buoyant force that was exerted on the object. Using the force sensor also showed how the forces on the object changed as it was lowered into the water and only part of it was submerged.

- Similar features seen in other essays more casually inspected
Session Level Variation

- Sometimes a student suddenly “gets it,” and later essays show significant improvement

Under a continuous model, the layer of a soap might be able to spread out indefinitely, but that does not fit the observation that, at some point, the soap will stop spreading over the surface of the water. (Poor use of commas.)

If the soap is made of atoms, then the soap could spread until the height of the layer of the soap is equal to the height of a soap atom, which would mean at a certain point, the soap could not spread anymore.

The sugar crystals were generally smooth with a few bumps and were relatively clear, which was much different from the salt crystals, which generally looked very rough, cloudy, and had an uneven. . .

- Many ideas jammed into single sentence; no control of sentences
Session Level Variation

Fracturing other solids in different ways ends up having similar results to the tearing of paper, such as when a silicon wafer is broken. Breaking the silicon, with the edge of the table perpendicular to the flat edge of the wafer, ended up making very uniform cracks with straight edges, and it appears to be easiest to break it this way. . .The fact that the solids that were examined so far broke in very specific ways under certain conditions suggests that there might be an underlying structure contained within them that determines how these breaks form.

• He’s regained control of his sentences, connecting experiments, making generalizations.
Rhetorical Indicators of Simplistic Vision

- Even the best students struggled to write a coherent paper that integrated activities with larger themes.

- Seen in certain rhetorical ways:
  - Introductions often “course-centered” (In class we...).
  - Very few (2/25) had conclusions. summary not necessary
  - Sentence transitions mostly chronological or non-existent

- Project reports significantly different
  - All had conclusions, more introductions were concept-centered
  - Transitions were more synthesizing
Question #1: Cognitive

What is the State of the Student While Writing?

- Are students cognitively engaged while writing? How/where are they focused: style? grammar? content? Are they reorganizing knowledge while writing or merely regurgitating?

- Interview student about motivations and behaviors, record student writing on laptop for use in facilitated interviews

  * e.g. when, where, and how does student revise
  * time on various tasks (intro, conclusion, transitions, etc.)
  * are specific types of revisions necessarily engaging
  * does cognitive engagement in revision lead to content learning?
Question #2: Curricular

What Assignment Prompts are Most Effective?

- Scardamalia et al. used explicit prompts, requiring students to complete paragraphs that began with (e.g.)
  - An important distinction is . . .
  - An explanation would be . . .
  - Another way to put it would be . . .
  - This experiment doesn’t prove atoms’ exist because . . .

- explicitly require revision of different types
  - rewrite
  - rewrite and shorten
Question #3: Pedagogical

How Much Formal Writing Instruction (in-class) is Needed?

- Suspect writing instruction must be in-class or else students won’t transfer skills (Larkin et al. suggests even linked courses insufficient)

- Must instruction come from a writing expert, content expert, or both?

- How much instruction and in what form?

- How to combine content and writing instruction to encourage transfer?
Writing in *EiP*, Trial 3: Forced Revision

- Students asked to write a 250 word essay then, after it has been turned in, told to re-write it, shortening it to 125 words

- Students “track changes” and submit electronic version

- Told that grading will in part depend on the nature their changes
Yes there is a connection because the forces determine how it moves through the liquid. With a small ball of clay tested in a jar of water to see if it would float. It immediately sunk to the bottom showing that the net downward force had to be stronger coming down than going up. The next object that we experimented on was a large bouncy ball that just floated on the top of the water. This showed us that the net force was zero because it was just floating on the water causing equilibrium between upward and downward forces. The last object that we used in our experiment was a ping pong ball. We took the ping pong ball and submerged it under water and it immediately rose straight up to the top. This showed that the upward net forces were much stronger than the downward net forces. There were two forces acting up on the ping pong ball which were buoyant force and the forces of the water pushing up from below. One force was acting down on the ping pong ball and that was the force of the water acting down from above. Because the ping pong ball was going up we know that the forces acting upward had to be greater than the forces acting downward.

First & last sentences independent: not a unified paragraph

* Sentences 1-2: Net downward force causes clay to sink
* Sentences 3-7: Net upward force causes ping pong ball to rise
Revising not Excising

• 125 words a good length, since you can’t get there just by cutting words

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• First & last sentences independent: not a unified paragraph

* Sentences 1-2: Net downward force causes clay to sink
* Sentences 3-7: Net upward force causes ping pong ball to rise

• What’s the single unifying idea? That’s what needs to be written about.
Successful Revising, Part 1: Recognizing Irrelevance

- first two paragraphs unnecessary...

At first, the idea of sinkers and floaters seems to require only a slight amount of common sense to understand. Yet, as our group studied further into this subject during class, I discovered that much of what I thought I understood about sinkers and floaters seemed to be incorrect. Of course, this is all part of the learning process that I hope to further undergo in class this quarter.

Originally, I viewed sinking and floating as a very cut and dry issue. It seemed simple to me that when you dropped something into a bucket of water, its physical properties decided whether it immediately fell to the bottom or remained at the surface. Then, our group began to look at the scenario of a partial submersion and tried to figure out what truly classifies an object as a sinker or a floater. Like most people would probably assume, we were sure that density and surface area must have something to do with sinking and floating. After all, a large cruise ship can float and a very small ball of clay will immediately fall right to the bottom of the water. We also predicted that air inside of an object would ultimately float better than one that was solid. This came from one test that we performed in which we dipped an empty vial into the water and watched it float. Then, we filled the vial with small pebbles until it was full and it sank. Still, we were not sure exactly what physics were in play here. We had predictions based on our observations, but still no solid evidence existed of what forces might play a role in this phenomenon.
Sinking and floating usually seems like a very simple idea. The activity that involved using force meters is the one that really opened my eyes to the world of sinkers and floaters. Even though this activity had nothing to do with water, the concepts finally fit together in my mind. Obviously, gravity is present in pushing something down towards the earth when it is dropped. In water. It was also obvious that there was another force pushing up on the floaters to keep them at the surface. There must also be another force from the water pushing on the object, but yet this force must be in equilibrium with gravity or the object would always move, simply fly up out of the water. We would call this a net force of zero, since the forces were in balanced. The upward force from the water that I mentioned was really the one that we had not understood previously to the activity and is called buoyancy. However, using the force meters and lifting weights slightly with our hands, but leaving enough hanging that the force did not drop to zero, I finally understood the idea of this buoyant force that is present in the water. While the water does not fully support the object entirely, it presses up on it just enough to create an apparent weight, though of course, the object's true weight still does not change. By taking this apparent weight and subtracting it from its real weight, we should be able to see how much force the water is using to push up on the object we drop into it. Subtracting these two weights, we can find the buoyant force. Once these forces eventually balance out, we end up with a net force of zero, causing the object to settle somewhere in the water. What decides if the object sinks or floats is where these forces balance out in the water. The zero net force occurs. Overall, sinking and floating is not too much of an advanced topic. However, at first glance it can be a little confusing or contradictory to what we think we already know. While this was the case for me, diving a little deeper into the topic and studying forces really helped me to understand sinking and floating.
Net force is the sum of the forces acting on an object. When looking at page D-6, we did an experiment on the pushes and pulls of immersed objects. The net force on the object was in a forward or backward movement up to the top or down to the bottom of the water. Would either push the object up or pull the object down. Gravity/weight force, density, buoyancy, water force, and other characteristics come into play here.

Part C asked us to push a floater wood being pushed to the bottom of the water and then released it. What happened was the result was the rise as that the net force for the wood pushed up on the wood to the surface. The air forces in the wood were pushing the wood up. However, when the rubber stopper sinker was placed at the bottom of the water, it had the opposite reaction. It was still sunk to the bottom of the water. While the force of the wood was stronger for the floater, the weight pull of the rubber stopper was stronger.

On page D-4 however, we were asked to have the object at the top of the water and see if it would float or not. The floater, being the wood had stayed above the water, while the sinker, the rubber stopper, went to the bottom. The wood can float because it is less dense than the water. The rubber stopper, on the other hand, is denser than water and it does not float. Through net forces of an object, we can see if objects can float or sink in water. From the pulling and pushing of the objects forces, it classifies a floater and a sinker.

- Note addition of transitions: “When looking at”, “However”, “While the force”, “Through”

- This level of revision indicates that something significant has happened inside the students head. Things now “make sense”.
Comparison Study

• Similar assignments given to Ohio State students in *Physics by Inquiry* classes, but no explicit writing instruction incorporated into class

• After quarter ends, Dedra Demaree (OSU graduate student) will compare the essays, looking for differences in writing style and types of revisions
Automated Writing Tracking and Analysis

- Track changes gives some clue to where students revise, but we’re still inferring a lot about the thought process of the students.

- Collaborating with Ohio State University to capture all key-strokes students make so we can see not just final version, but all changes.

- Working on a web-based version as well.
Sample Essay

In order for a bulb to light you need a closed circuit, meaning there needs to be the flow of a current from a battery to a closed switch then to one terminal of the bulb and out the other back to the battery. An Open circuit means the switch could be open and the flow is being stopped at the switch coming from the battery and not completing the circuit and not lighting the bulb. A Short circuit is when the switch is closed meaning the flow is circulating from the battery through the switch through the bulb back to the battery and so on, yet the bulb is not lighting meaning a connection is messed up.

- Tags identify both typing, pauses (Pa)
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<th>Action</th>
<th>Text</th>
</tr>
</thead>
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</tr>
</tbody>
</table>
S-notation (Kollberg, 1996)

- Insertions {} and deletions () marked, as are interruptions ||

  I am writing a {short} text. || I will (probably) be revised (somewhat) later. || Now (I am) it is finished.

- Decoding:

  * “I am writing a text.”
  * “short” inserted
  * “It will probably be revised somewhat later.”
  * deleted “probably” and “somewhat”
  * “Now I am”
  * deleted “I am”
  * it is finished.

*I am writing a short text. It will be revised later. Now it is finished.*
We can do better!

- In collaboration with Jeff Pelz at RIT’s Center for Imaging Science, we’re investigating the use of eye-tracking technology.

- Now we know where they look before they type, and can ask new questions:
  ∗ How do students read their essays while they revise?
  ∗ How far back/ahead do students read before making a revision?
  ∗ Is revision characterized by a few key, intense, events?

Eye-tracking video

- Note what cues student to write intro sentences, how he revises.
Conclusions

- Research on writing has been reactionary and not bridged the gap between acontextual cognitive studies and hermeneutical theories.

- In attempting to bridge this gap, three questions must be addressed:
  1. What Assignment Prompts are Most Effective?
  2. How Much Formal Writing Instruction (in-class) is Needed?
  3. What is the State of the Student While Writing?

- Assignments that explicitly require difficult revision (i.e. cutting length in half) are promising.

- Just beginning to scratch surface of other questions (especially #3!)