Using Student Notecards As An Epistemological Lens

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Abstract. In an effort to shift course goals away from equation memorizing, I allowed two different introductory physics classes the opportunity to prepare a card or sheet of notes for the exams. I analyze and categorize the items students choose to include on a case-by-case basis. Students include some mixture of definitions (both mathematical and otherwise), equations (both general and specific), unit information, physical constants, statements of laws or concepts, math review, guides to symbols and variables, diagrams, and worked examples. I compare my two classes, look at some individual students in depth, and try to gain insight on how we can use these artifacts to see what students perceive as important in the courses (or at least what's worth committing to paper).

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INTRODUCTION

Previous research has used methods such as interviews [1] or multiple-choice surveys [2] to gain insight into student epistemologies (defined here as context-dependent beliefs about the nature of science and learning). In this brief study, I seek ways of gleaning epistemological insight from the notecards and sheets students prepare for their final exams.

My main research questions are: (1) In what different ways do different students choose to use the allowed note space? (2) Can we find associations between what students choose to include and their exam performance? (3) What can student notecards tell us about what the students see as important in the course and what might be examined?

Columbia College Chicago is one of the largest arts and media colleges in the USA. As such, we have no physics majors, and most students neither major nor minor in science. We offer several classes that fall under the umbrella of physics, but the two that focus on mechanics are Physics for Filmmakers (PfF) and Fundamentals of Physics I (FoP I). These courses provide the present study's population.

COURSES AND STUDENT POPULATIONS

The courses in this study are both algebra-based introductory mechanics courses. Physics for Filmmakers [3] (PfF) uses clips from action and science fiction movies to motivate discussion about kinematics, dynamics, collisions, energy, and other mechanics topics. Labs are often filmed and analyzed using Tracker [4] software. Most of the students in this class come from the Film and Video department. The goal of the course is to help them make more deliberate choices when depicting physics in their artistic work. Students must complete a final project where they demonstrate correct physics in a film they create. Though the class started out with nineteen students, thirteen completed the final exam.

The Fundamentals of Physics I (FoP I) has more traditional mechanics course coverage. The Fall 2011 version of the course featured eight students, most of whom were Audio Arts and Acoustics majors enrolled in our first Bachelor of Science program. Course activities included traditional lectures, labs (some in common with PfF), tutorials, and demo-centered discussions.

FoP I included more mathematics, including a small amount of trigonometry which was not a PfF prerequisite. There was still noticeable overlap between the final exams for the two courses, especially on conceptual questions.

Previous courses taught together with faculty colleagues at Columbia allowed students to use their textbooks for the final exam, but that created problems since students would spend too much of the allotted exam time looking things up in the book. The goal in letting them use written notes is that we can mitigate the "textbook research" problem and collect the note sheets as data to see what they saw as important to include. Students were allowed a 4" x 6" notecard for the midterm and one side of an 8.5" x 11" paper for the final exam. This study focuses on their final exam note sheets.

DATA AND ANALYSIS

Preparation and Collection

For both courses, students were informed well in advance that they would be allowed to bring notes to the exam, and they were told they could use the paper space in any way they wished. Participation was optional, and no points were given for the notes. Students were also informed that the final exam would consist of multiple sections. Both the PfF and FoP I exams featured two major parts: a conceptual section containing multiple choice items, short answer problems, and graphing representations, and a more mathematical section where facility with equations is more useful.

All test takers with the exception of one FoP I student chose to prepare a final exam note sheet. They varied a great deal in focus and writing density, which I will discuss in a later section. Notes were collected at the end of the exams. Midterm exam notecards were returned to the students, but the final exams and note sheets were not returned.

Classification of Note Sheet Artifacts

After briefly reviewing several examples of the student data, I came up with a scheme for classifying what the students chose to write. My initial set of categories includes the following:

- *Definitions* (often in equation form) – such as the definitions of average velocity or angular acceleration.
- *Equations* – these include both general laws written in equation form, equations derived from definitions, and equations that can be used for specific problems only (for example, the acceleration of masses in an Atwood machine). A separate category was created for worked numerical examples.
- *Units and conversions* – these include both the MKS breakdown of common units like the Newton or Joule and simple conversions (such as 1 mile = 1609 m or 1 cal = 4.18 J).
- *Physical constants* – such as the universal gravitation constant, the density of water, etc.
- *Conceptual statements* – This classification came into play when students wrote out conceptual ideas in words.
- *Guides to symbols* – Students do this to understand their equations better, for example, one may write "v_0: initial velocity."
- *Pictures and diagrams* – These were either pictures drawn to support equations or examples or were themselves examples of position, velocity, or acceleration graphs.

Classification Overlaps and Subdivisions

Much of my coming analysis will be qualitative due to the low number of students in my classes, but even if that were not an issue, there are difficulties inherent in this classification system. One of these difficulties is category overlap. As mentioned earlier, definitions can be given in equation form. Though the expression $\vec{a} = \Delta\vec{v}/\Delta t$ is technically an equation, I would classify it as a definition first.

Some students chose to copy entire derivations, thereby writing several steps that were counted as equations. For example, a popular writing on the note sheets was the derivation of Kepler's Third Law, starting with an equation setting the gravitational force expression to the centripetal force expression and working in steps from there.

I could have attempted to break the equation category down even further since different equations have different ranges of applicability. For example, Newton's Law of Gravitation, though not useful in all problems, has a wider range of applicability than the equation which gives the acceleration of two masses set up as an Atwood machine.

As mentioned earlier, the "diagrams" category served multiple functions as well. They sometimes were free body diagrams such as those used to draw forces acting on an object on an incline. Others came from examples the students saw in lab where they had to predict and discover motion graphs for carts undergoing constant acceleration.

Preliminary Observations Regarding Exam Scores

With such low N (7 for FoP I and 13 for FfP), even a strong numerical correlation between notecard content and exam scores is suspect, but I looked for qualitative patterns to preview what I might see in a larger study.

For the PfF course, students averaged about 60 code-worthy statements on their final note sheets. Two of the thirteen students had more than one hundred items, and one student had only ten. Six of the top seven final exam performers represent the top six students in terms of note sheet item density. The seventh, a student who got overall the highest mark in the class, showed that he only needed a basic equation list to make it through the test. It seems here that in for this course, students who prepared more notes performed better on the exam overall. I could not draw any conclusions about how student inclusion of drawings relates specifically to their graphing performance since eight of the thirteen note sheets had no drawings or diagrams at all.

Different patterns emerged in the FoP I final note sheet data. For one, the sheets were a lot more extensive. The seven prepared sheets had an average of 97 items on them, and the least-dense sheet among the seven was more extensive (at 67 items) than the average PfF note sheet. This is not terribly surprising, given that the FoP I course covered far more conceptual and mathematical material.

There did not appear to be any correlation between the number of items on a note sheet and exam scores. Among subdivisions consisting of the two densest note sheets, the two least dense, and the three in the middle, an exam score significantly above the median and a score significantly below the median can be found. This means that for my small sample, just looking at the number of note sheet items does not predict how the student will do on the exam.

Case Studies: How Do Different Note Sheets Look Different?

Comparing Two Dense Sheets in FoP I

In the Fundamentals of Physics I course, two students (given the pseudonyms Carl and Gary) who prepared the most intricate note sheets performed very differently on the test. Carl earned a high B on the final, while Gary earned a D. Of course, this is largely due to factors other than their note preparations: Carl attended office hours far more frequently than Gary, put more time into his homework, and asked more questions both in class and outside class via e-mail. Still, I wondered how their approaches with respect to their note sheets would differ.

In my preliminary count, Carl's note sheet had 130 countable items, and Gary had 122. However, on first glance, these totals are surprising: Gary's sheet seems far more dense and hard to read. The cause of this is Gary's inclusion of 21 complete, worked examples. These worked examples often include a few sentences of setup, an occasional picture, and a solution. Some problems done this way include a conservation of energy problem where a rocket leaves Earth's surface at a speed about half the escape velocity, a pendulum problem where length must be calculated given a period, and some kinematics problems. Many of these were taken directly from either notes or homework.

Gary's note sheet was the maximum size allowed (8.5" x 11") with the smallest print among all my samples. Carl's was on slightly smaller paper, and included no fully-worked examples. The two sheets were the same in that both included some side-by-side representations of position, velocity, and/or acceleration graphs.

Though both employed some form of organization into blocks, Carl's sheet had topic headings on the top of each small block that were colored in yellow highlighter. Also, his sheet was arranged with some attention to course chronology: basic kinematic equations and projectile problems were shown at the top left, while material near the end of class (specifically things like rotational dynamics, simple harmonic motion, and fluids) were down on the lower right. One useful place this pattern was broken is in the kinematic equations; though he put rotational dynamics near the bottom right, he put analogous rotational kinematic equations near their linear counterparts. Otherwise, there was very little mixing of disparate concepts within a close space on Carl's sheet. Though Gary made some mention of rotations near his kinematic equation boxes, he did not do as thorough a job linking linear and rotational variables. Instead, he did some worked conversions between angular displacement and velocity units.

Gary's note appeared organized at first, but the topics were a little more disjointed: going from top to bottom on the left side, his topics included fluids, two Kepler's third law problems, an escape velocity question, a one-dimensional free fall, a two dimensional free fall, then 1-D motion graphs. Escape velocity was referred to in two completely different parts of the note sheet, but the derivations he wrote down were nearly identical. A Kepler's Third Law derivation was recreated very far from the problems where he used it. A cluster of problems in the center of the sheet included a spring conservation of energy problem, a torque question, a diagram of centripetal force, and a conceptual picture showing a rolling sphere versus a rolling ring. Though a lot of Gary's preparation was correct and thorough, one can easily see how hard it would be to navigate his sheet.

In summary, though both students spent a long time making a very thorough note sheet, I hypothesize that Carl's was more useful because it was more compact, easier to navigate visually, and organized in a clearer way. Gary's sheet duplicates the issues many students have during an open book test: it containted too much information, and relied excessively on prewritten worked examples. Perhaps this latter reliance was caused by a hope that I'd duplicate older questions more exactly on the exam.

Comparing Note Sheets Among Two PfF Students

Another interesting comparison comes from the Physics for Filmmakers course. Two students there, who I will call Hal and Mark, had A averages going into the final and wrote note sheets for the final with similar numbers of items (52 to 59 respectively). However, the balance of content each student chose to write about was very different. Hal spent a lot more of his note space with guides to the various symbols in his equations and proper units for the quantities involved. As an instructor, I encourage this, but his content coverage suffered: half his paper discussed only kinematics and Newton's 2^{nd} Law, and a majority of the other half covered buoyancy. He only made passing mentions of inelastic collisions, centripetal acceleration, and Kepler's 3^{rd} Law. This quick analysis shows one reason why a simple counting of note sheet items and their types might not tell the whole story of a student's note preparation.

Mark's note sheet was much less wordy than Hal's, and consisted almost entirely of equations. References to the symbols or units were minimal, and a majority of his conceptual statements took the form of an email I sent him earlier in the course regarding the concepts behind escape velocity. His equation ordering was approximately chronological, and he covered topics from throughout the semester. Again, acknowledging that this note sheet is not the only preparation they made, I note that Mark earned an A on the final while Hal earned a D – an uncharacteristic score for him.

FUTURE STUDIES AND TEACHING IDEAS

Making a More Pointed Epistemological Instrument

As it stands now, the note sheets studied here can give us insight into what students see as either not worthy of memorization or handy to have as a reference. We might also see how these equations, pictures, and ideas are organized by the students. Without any follow-up questions or interviews, though, we are limited as to what we can conclude. We might ask students (with points offered for answering thoughtfully) something like, "How did you decide what to put on your note sheet?" That way, students can say how they organized things, whether they were seeking to simply avoid memorization or understand derivations, or if they just decided to write down anything remotely mathematical from their textbooks. Other potential follow-up probes might ask the student how much time he or she spent creating the note sheet and how much the student thinks the sheet helped on the test.

It may also be interesting to refine my content coding scheme and then apply this to a larger number of students. If analysis is then done for, say, a larger lecture course at a university, we can have more robust findings one way or another regarding connections between sheet preparation and student performance.

Formative Assessment

Though I have focused here on how well student note sheets give insight into either what students see as worthy of recording or how they organize information from the class, it is possible that the best application of studying exam note sheets is to do a mid-semester formative assessment. The note sheets can be studied according to their topical coverage and balance between equations versus conceptual ideas.

One reason I regret not trying this with the midterm exam is that students occasionally make mistakes on the note sheet. Six of the PfF students and four of the FoP I students had at least one equation or other item on their note sheet that was incorrect. Three of the PfF students had four or more incorrect items on their notes. That was a correction opportunity I missed. Also, though students might profit from writing out entire worked examples on their note sheet, this may not serve them on an exam with slightly different twists on those examples. At midterm time, I can identify cases where that happens and provide appropriate feedback to the students.

Another possibility for assessment is to build a notecard writing activity into the course. By turning this exercise into an assignment we can all discuss together in class, it may refine the students' processes and study habits well before the exams.

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