Science Faculty Grading of Quantitative Problems: Are Their Values Consistent with Their Practice?

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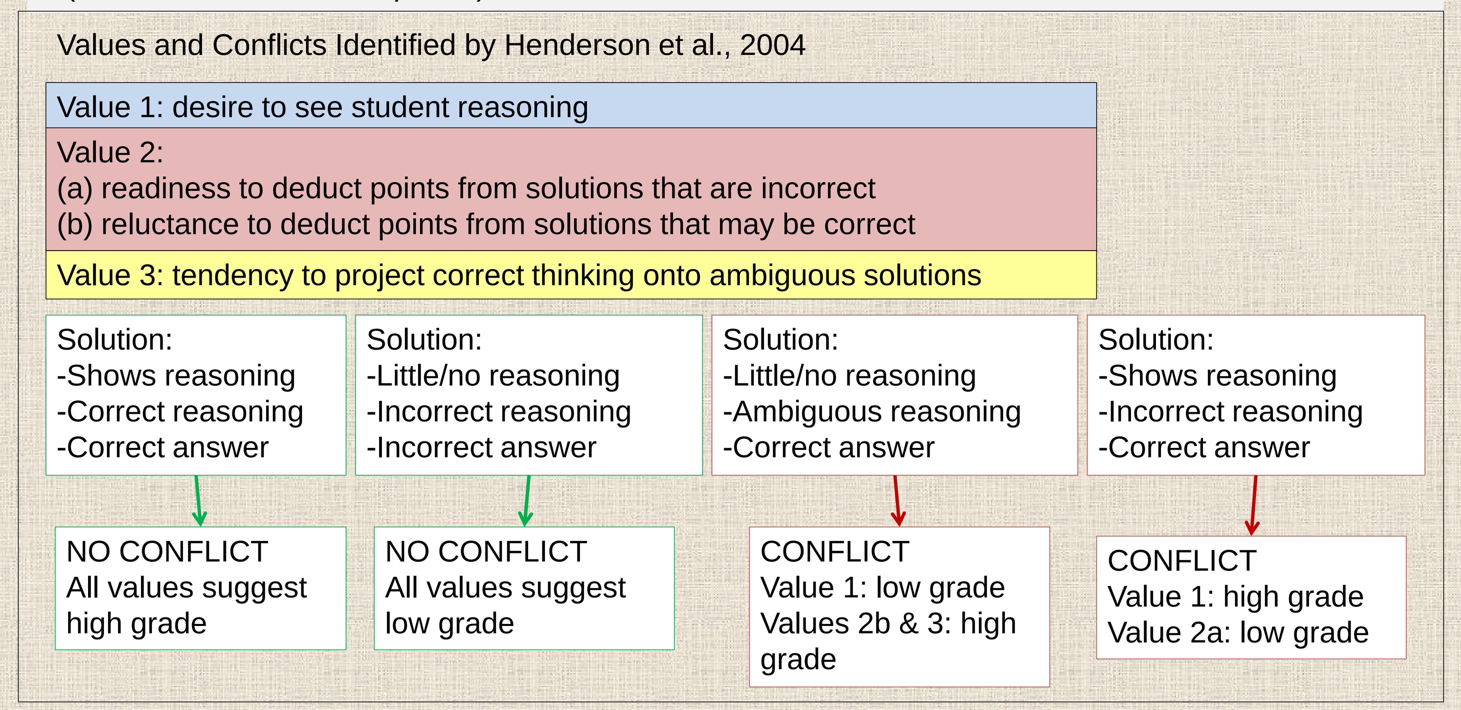
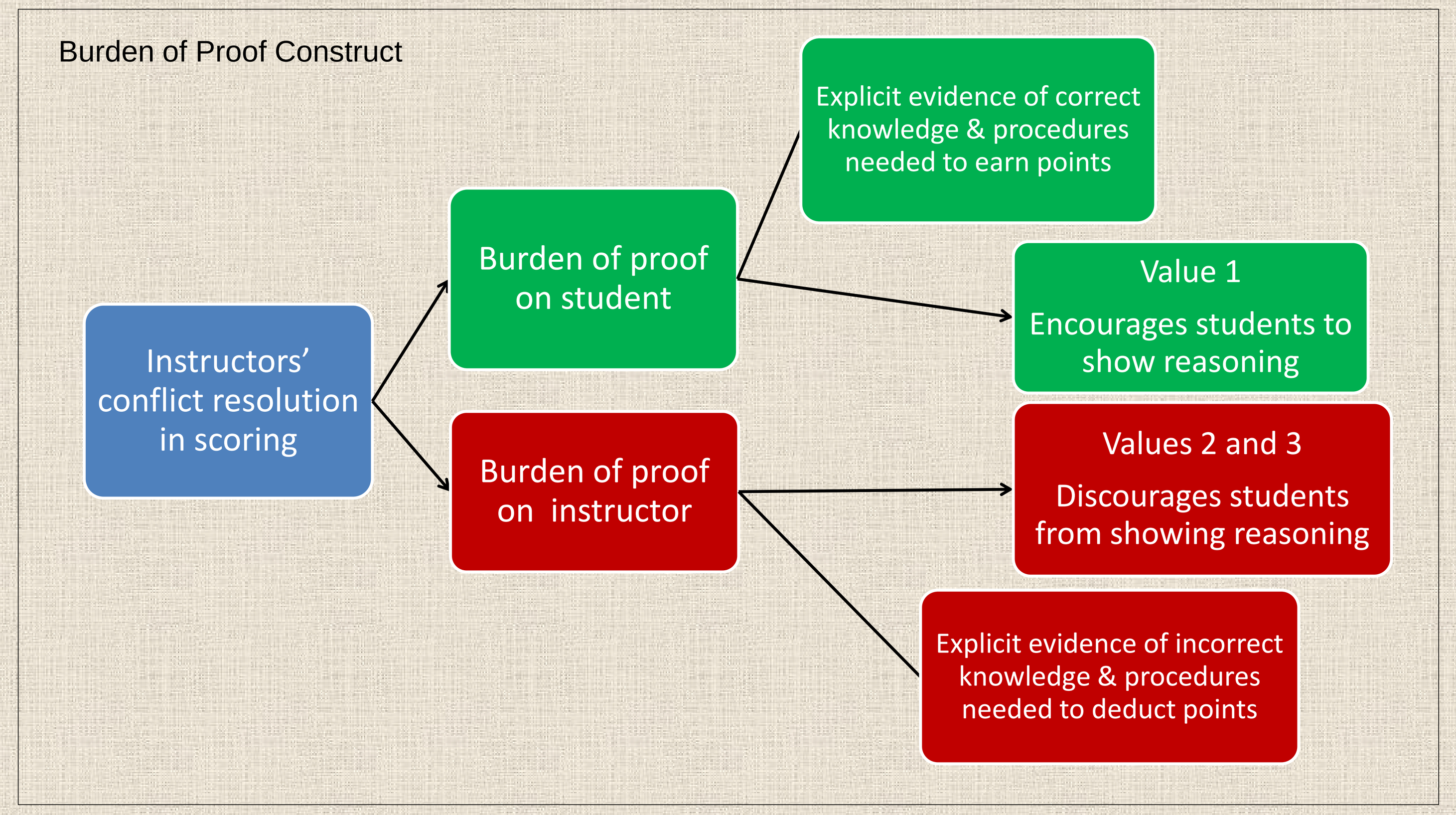
ABSTRACT

Grading practices can send a powerful message to students about what is expected. Research in physics education has identified a misalignment between what college instructors value and their actual scoring of quantitative student solutions. This work identified three values that guide grading decisions: (1) a desire to see students' reasoning, (2) a readiness to deduct points from solutions with obvious errors and a reluctance to deduct points from solutions that might be correct, and (3) a tendency to assume correct reasoning when solutions are ambiguous. When values are in conflict, the conflict is resolved by placing the burden of proof on either the instructor or the student. In this qualitative interview study, we verified that this misalignment exists and that the same three values are present among earth science (n=7) and chemistry (n=10) instructors. Furthermore, we identified a fourth value regarding the desire to see the correct use of units. Overall, we found that 43% of earth science and 60% of chemistry faculty placed the burden of proof on the student; we speculate that the nature of chemical problem-solving may account for this difference. Although all of the faculty in this study and the physics study stated that they valued seeing student reasoning, only 49% overall graded work in such a way that would actually encourage students to show their reasoning, and 34% of instructors could be viewed as penalizing students for showing their thinking. This research may contribute toward a better alignment between values and practice in faculty development.

BACKGROUND

- Feedback from the instructor to the student, typically in the form of a grade, has a powerful effect on student learning (e.g., Black & Wiliam, 1998, Elby, 1999; Schoenfeld, 1988).
- Grading practices, therefore, can have a tremendous impact on what students do in a college course.
- Research in physics education has documented a tension between what instructors say they value in grading quantitative, free-response student problem solutions, and their actual grading practices (Elby, 1999; Henderson, Yerushalmi, Kuo, Heller, & Heller, 2004).
- **Many instructors say they want to see reasoning in a student solution to make sure that the student really understands, but then grade in a way that penalizes students for showing their reasoning, or rewards omitting clear reasoning.**
- Henderson et al. (2004) propose that this tension exists because hidden internal values conflict with expressed values.
- These authors develop the construct of "burden of proof" to explain how faculty resolved these conflicts (Henderson et al., 2004, p. 167).





PURPOSE AND RESEARCH QUESTIONS

- Our goal is to extend the Henderson et al. (2004) study with faculty in chemistry (n=10) and earth science (n=7), in order to document whether the misalignment between explicit values and grading practices exists across science faculty more generally.

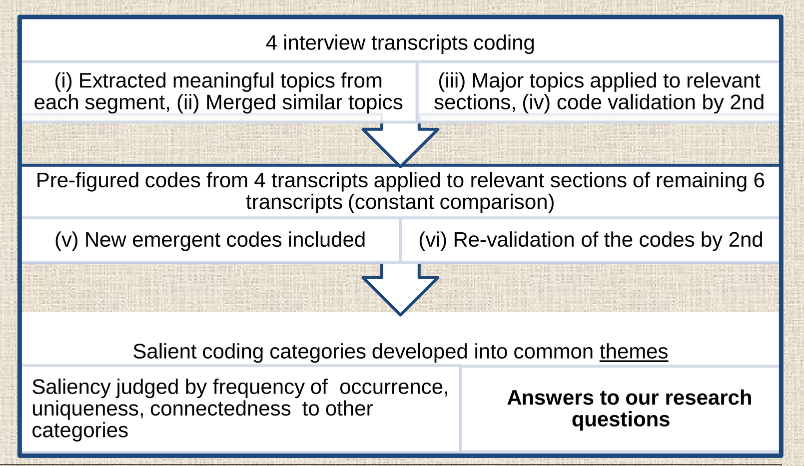
1. Which, if any , of the previously identified values are expressed by chemistry and earth science faculty as they grade quantitative problems?
2. How do faculty from chemistry and earth science weigh expressed and implicit values in their grading decisions?
3. Are chemistry and earth science faculty more likely to place the burden of proof on themselves, or on the student when grading student work?

METHODS: Student Solutions

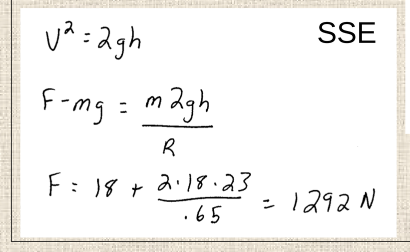
- Typical quantitative, free-response problems encountered in an introductory, college-level course (stoichiometry, adiabatic rise).
- Solutions are based on examples of actual student work.
- 5 student solutions that mirror the original 5 physics solutions (Henderson et al., 2004).
  - Student Solution D (SSD): shows student thinking, has explicit errors, has correct answer.
  - Student Solution E (SSE): does not clearly show student thinking, but has correct answer.
  - **SSE could have made the same combination of errors as SSD, or could have done the problem correctly; the reasoning expressed in the solution is ambiguous.**
  - SSD and SSE designed to elicit conflicts between values.
- Obvious errors were identified by boxed comments.

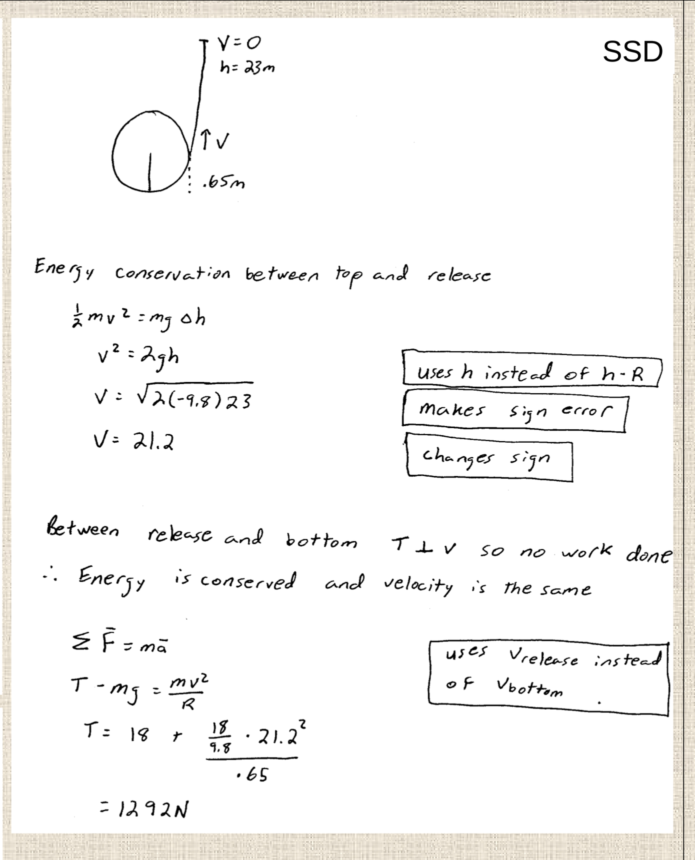
METHODS: Interviews and Analysis

- Recruited full-time faculty at research-intensive universities within a 3 hour drive, who had taught introductory chemistry or physical geography within the past 3 years.
- Subjects were emailed the problem prior to the interview and asked to solve it.
- Audio- and video-recorded individual 30-60 min interviews in which subjects:
  - Ranked student solutions from best to worst and assign each a grade out of 10 points (subjects assume students are familiar with instructor's grading practices.
  - Explain, as best as possible, student thinking reflected in each problem.
- Transcription and thematic coding of data largely based on *a priori* themes identified by Henderson et al. (2004), but also allowing for additional themes to arise from the data (e.g., Creswell, 2003).

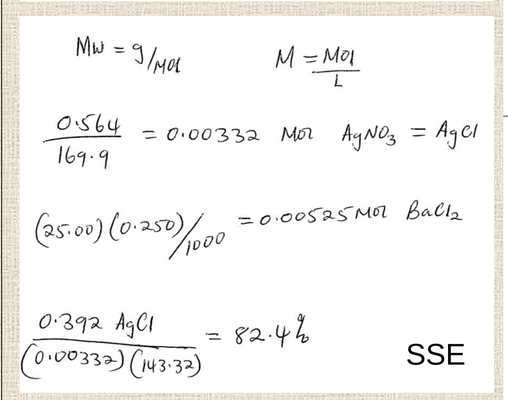


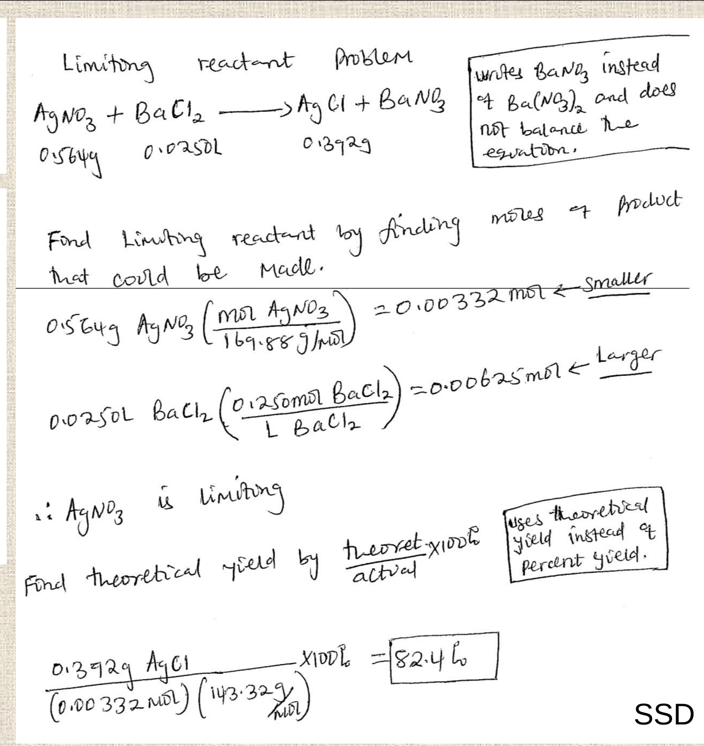
(A) PHYSICS: You are whirling a stone tied to the end of a string around in a vertical circle having a radius of 65 cm. You wish to whirl the stone fast enough so that when it is released at the point where the stone is moving directly upward it will rise to a maximum height of 23 meters above the lowest point in the circle. In order to do this, what force will you have to exert on the string when the stone passes through its lowest point one-quarter turn before release? Assume that by the time that you have gotten the stone going and it makes its final turn around the circle, you are holding the end of the string at a fixed position. Assume also that air resistance can be neglected. The stone weighs 18 N.



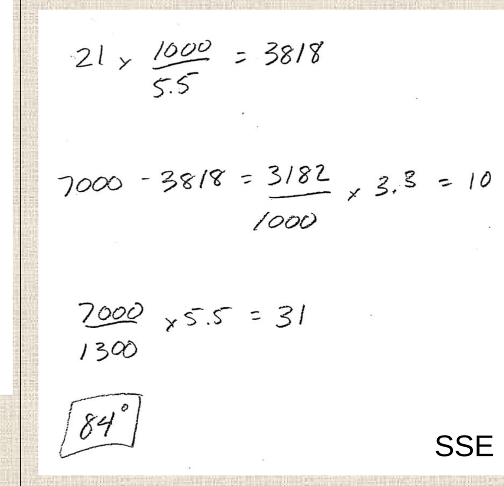


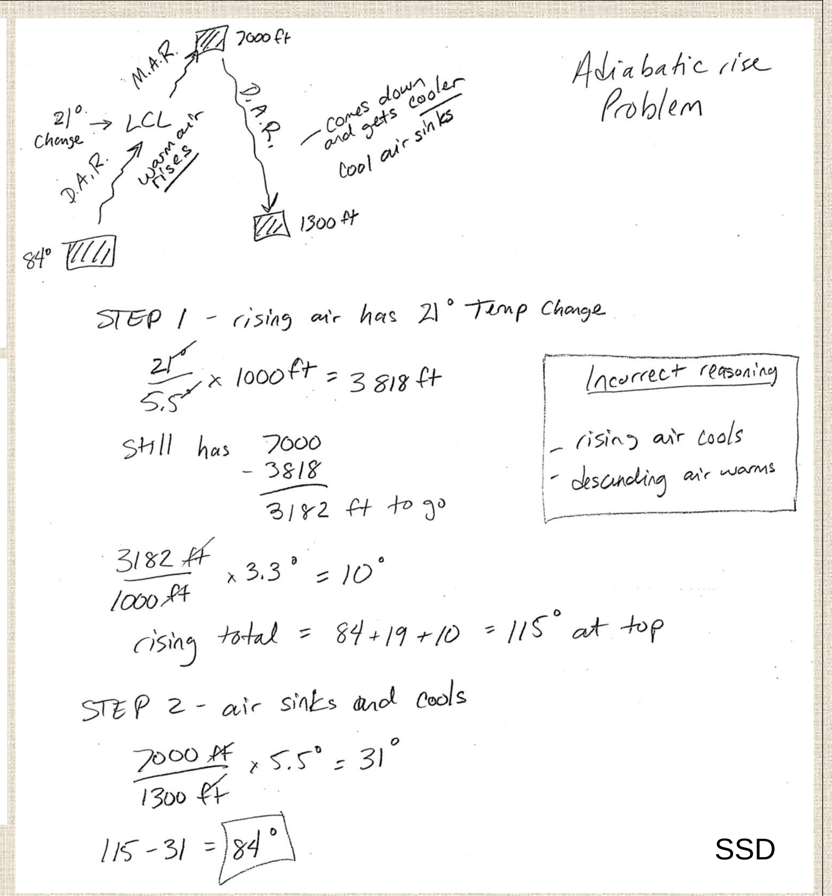
(B) CHEMISTRY: 0.564 grams of $AgNO_3$ is dissolved in 25.00 mL of 0.250 molar $BaCl_2$. A precipitate forms and is isolated and weighed. Its mass is 0.392 grams. What is the percent yield of the reaction?





(C) EARTH SCIENCE: An air parcel is forced to rise over a mountain to a height of 7000 feet. The air parcel's starting temperature is 84 F at sea level on the windward side of the mountain. It reaches its dew point at approximately 63 F. What is the approximate temperature of this air parcel when it descends back to 1300 feet on the leeward side of the mountain? Assume that the air parcel is not saturated during its descent.

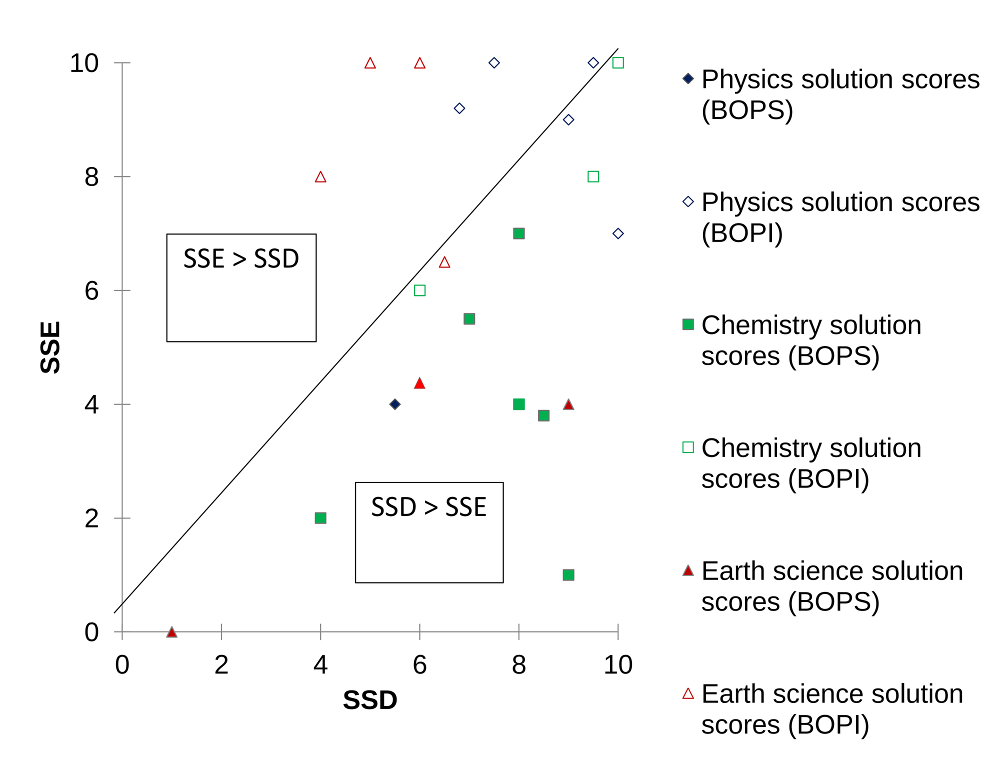




RESULTS

- **Same three values previously identified among physics faculty by Henderson et al. (2004) were present, plus a 4th value.**

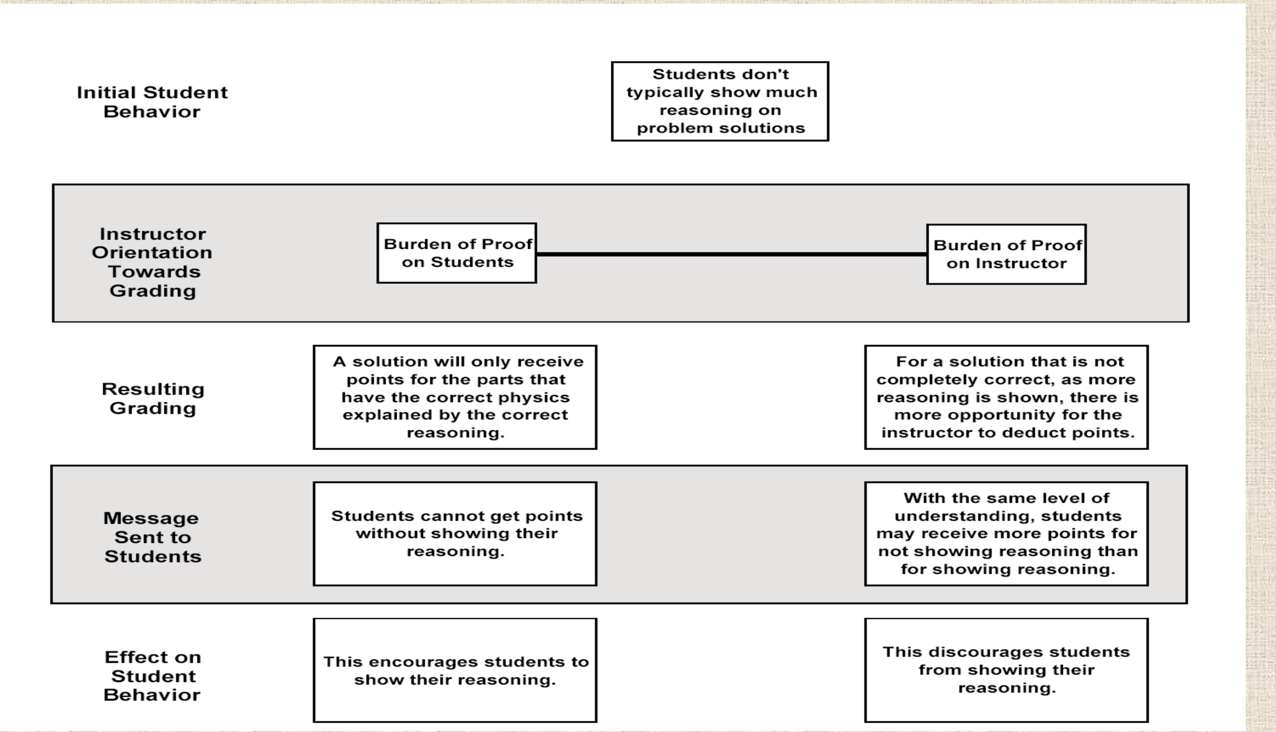
Value	Chemistry example	Earth Science Example
1: Desire to see student reasoning to know if the student really understands	Instructor C7: "I appreciate student solution D because it does give me a chance to better understand what the student was thinking as they did the problem… at least my ability to interpret whether they are in need of some guidance, I think, is much easier. For student E… [I would not] be able to say 'this I believe is where you made a mistake…'"	Instructor E3: "I always say show your work….and diagrams would be helpful. …diagrams would be helpful for the people who would have gotten partial credit - at least I see where they messed up."
2a: Desire to deduct points from solutions that are clearly incorrect	Instructor C8: "This one [SSD] on my scale, that's minus two for not balancing the reaction; they did the problem [compared moles] both correctly; that's based on that [the limiting reactant has smaller moles], so they got that. So they get 8 out of 10."	Instructor E2: "This student [SSD] complied with expectations but did not think it through correctly….wrong numbers and wrong physical processes…severe problems, I'd give a one [point] because there is work shown… [but] reasoning is wrong."
2b: Reluctance to deduct points from solutions that might be correct	Instructor C4: "student solution E has got the correct answer and he used a very simple way to write the solution, but all the stages are right; all the conversions are correct, so I give him 10... I try to give [students] more credit as long as they write something which seems right."	Instructor E3: "Well, this person [SSE] didn't show their work, but they got the right number and it looks like they did everything right. I guess we've got no choice but to give them a 10."
3: Tendency to project correct thinking on to ambiguous solutions	Instructor C7: "This student [SSE], I think this student knew what they were doing; they actually had the ability to do all of the detail work… they clearly indicate what they know about stoichiometry and solutions at the top, but I just think that they felt like they didn't have to write down any details."	Instructor E1: "[SSE has] no organization, no units, and it's impossible to follow the logic. I always debate on this how much to penalize because I always say to show all work. There is enough chicken scratching for me to know they knew what they were doing, so it's a minor penalty."
4: Desire to see an organized, methodical solution with units clearly labeled	Instructor C5: "When I give a problem and I say I want these elements in the problem; I want the correct reaction balanced or charges; mass; I want quantities labeled; I want the units in there and if you do that even if you get the problem wrong you gonna get a half credit."	Instructor E7: "And, you [the student] can't just throw some numbers together in your head and get an answer - you have to check your units. You have to draw a picture. You have to identify what's known, and most importantly, identify what's unknown."



	Chemistry Example	Earth Science Example
Burden of Proof on the Student	Instructor C6: "there's no explanation how it [the problem] was done, I cannot see…. if the student knew this or if it was just copied from somewhere. So this student [SSE] might actually be better than this one [SSD] but since the method of solving the problem is not exposed correctly, I cannot grade that work."	Instructor E2: "I don't really know what student E was thinking… I fault student E because nothing is labeled, crudely the work is shown… it's not clear what the work refers to. Personally I'm irritated by this kind of scant answer."
Burden of Proof on the Instructor	Instructor C4 : "I don't like [SSE]E - although he or she may be smart to get the correct answer and everything right, but from a simple writing you cannot check his thinking, you know. I don't want to take any credit off but I will just tell him directly that he should give people a little more writing to enhance understanding just in case the final result is wrong."	Instructor E3 : "Well, this person got it right and it looks like their logic was right. That's the best paper so far, even though they didn't draw a nice mountain. Guess they just knew it cold and didn't need to put it together like I do."

CONCLUSIONS AND IMPLICATIONS FOR PRACTICE

- Including 30 surveys and 6 interviews physics from Henderson et al. (2004):
  - 49% of faculty could be viewed as providing students incentive for showing their work (e.g., graded SSD > SSE)
  - 34% of faculty could be viewed as penalizing students for showing work, and rewarding omission of work (e.g., graded SSE > SSD).
  - 48% of faculty placed the burden of proof on the student, requiring students to prove knowledge in order to earn points.
- Chemistry were more likely than earth science or physics faculty to grade SSD > SSE. The nature of chemical problem-solving may account for this difference (Camacho & Good, 1989).
- This research can serve as a tool to promote cognitive conflict in faculty. This cognitive conflict can in turn lead to reflection on and changes in practice.



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