and to reinforce what they have learned, perhaps compromising the durability of their learning. The 2e code demonstrated deeper reflection, including an analysis of initial ideas, but fewer than 5% of responses received this code. Students with consistent reflections receiving the 2a or 2b code essentially restated their pre- and posttest responses. These reflections seemed to "cut and paste" the pre- and posttest responses with no commentary or analysis. Students in these groups did not generalize their understanding beyond the two carts context, suggesting that they have not internalized Newton's 2nd law as a robust model of how the world works.

Inconsistent reflections. Fully one-third of student reflections were coded as *inconsistent.* Many of these students, representing about 13% of the total sample, did not identify an evident change in their reasoning. For example, one student explained on their pretest, "the lighter mass cart would have had a weaker force push to get it started, and so I think it would take less time for the fan's force to overcome it." On their posttest, they stated, "the [cart] with less mass would be the first one to stop and start moving back towards me as it has a greater/higher rate of change of speed than the heavier cart." On the reflection, the student explained, *"*I believe my original ideas were consistent with my current understanding. I thought that the lighter weight would turn back first.*"* The student does not seem to recognize that their final explanation incorporated a strong rate of change of speed concept, which was absent in the pretest. Nearly all students that failed to identify a fundamental change in reasoning had the same *answer* on the pre- and posttest. This suggests a tendency to focus on the answer, rather than the underlying reasoning, when reflecting.

Even among the consistent reflections, student language often indicated a focus on the answer. Many students used words such as "ideas," "explanation," and "understanding" when they seemed to be referring exclusively to their answer. Failure to differentiate answer from explanation could impede meaningful reflection on changes in understanding of force and motion. Other students giving inconsistent reflections, representing an additional 15% of the total sample, seemed to overestimate their level of initial understanding. These inconsistencies may stem from a form of hindsight bias.

V. CONCLUSION

We have developed a method for assessing reflective metacognition in the context of the learning of specific physics content. We find that one-third of the students describe their own learning in a way that explicitly contradicts researcher analysis of their physics explanations. We additionally identify distinct patterns of metacognition: some students restate their initial and final response, without really reflecting at all, some generalize by identifying a learned concept, and still others go on to connect their new ideas to their previous thinking.

We acknowledge limitations in our approach. Student reflections, as a group, vary considerably. We thus consider our coding scheme to have limited precision, in essence describing "dense regions" on a continuum. Furthermore, students' internal mental dialogues may include reflection that is more substantial than what is expressed in writing. Therefore, future work may include interviews to probe student metacognition in more depth.

The ability to track one's own thinking is important for the durability and transfer of learned content, and for guiding the learning of others. It seems unlikely that teachers unable to recognize changes in their own understanding will be effective in fostering student metacognition. We suspect that improvement in reflective metacognition requires exposure and practice over multiple courses, and advocate further study of the development of metacognition over time as well as the links between metacognition, content learning, and teacher practice.

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