Exploring alternative perspectives through fictionalized student dialogues

Thanh Lê and Andrew Boudreaux
Department of Physics and Astronomy and Science, Math and Technology Education Program, Western Washington University, Bellingham, WA, 98225

Jayson Nissen
Nissen Education Research and Design, Slidell, LA, 70458

Research-based instructional strategies often use fictionalized student dialogues (FSD) to encourage students to explore diverse ideas and perspectives. This study investigates the effectiveness of one such FSD in facilitating the exploration of alternative perspectives on the change in speed of a cart tapped by a finger. In one perspective, change occurs continuously during the tap, while in the other, change occurs instantaneously. We collected classroom video of eight groups discussing the FSD, and apply the socio-metacognitive framework of Borges *et al.* in our analysis. Five groups exhibit moderate- to high-level exploration of the contrasting perspectives, including one group that challenges the instantaneous perspective by drawing on the real-world experience of driving a car. Conversely, groups with low- to moderate-level exploration discontinued exploration upon seeking the “right” answer. Findings suggest that FSDs can support the exploration of alternative perspectives, and that instructors can enhance exploration by emphasizing real-world experiences and discouraging “answer-making.”

2023 PERC Proceedings edited by Jones, Ryan, and Pawl; Peer-reviewed, doi.org/10.1119/perc.2023.pr.Le

I. INTRODUCTION

Student-centered, research-based materials and curricula often use *fictionalized student dialogues* (FSDs) to present students with multiple perspectives on a physical phenomenon. Tutorials in Introductory Physics [1], Next Generation Physical Science and Everyday Thinking (NGP) [2], and TIPERs [3] all use FSDs. An FSD encourages students to explore contrasting perspectives and ways of reasoning about a specific concept or phenomenon, a habit of mind that underlies many scientific practices [4]. In an FSD, two or more fictitious students present contrasting explanations, which are then discussed and evaluated by the students. The contrasting perspectives generally derive from the research base: the fictitious students voice specific lines of thinking known through research to be common. FSDs have been useful in part because specific difficulties are often persistent. Research shows that simply pointing out an incorrect line of reasoning, and emphasizing how it differs from the normative reasoning, does not usually improve functional understanding [1, 5]. Once learners adopt a flawed explanation, they can be vulnerable to confirmation bias, in which they focus on supporting the initial explanation and do not actively consider alternatives [6, 7]. While research has shown the efficacy of activities that include FSDs [8], details of the learning dynamics have to our knowledge not been studied.

Socio-metacognition refers to how groups monitor and regulate their interactions and collective learning processes [9–12]. Theories of socio-metacognition align with the sociocultural nature of student-centered instruction, including FSDs. One such framework, from Borge and colleagues, includes a communication pattern of particular relevance to our study: *exploring alternative perspectives* (EAP). EAP refers to the extent to which a group presents and discusses alternative opinions, claims and ideas [11].

Groups with a strong tendency toward EAP may be more likely to benefit from learning activities that involve FSDs. To investigate the role of exploring alternative perspectives in groups' engagement with fictionalized student dialogues, we asked the following research question: *To what extent does a fictionalized student dialogue, with two contrasting ideas about the concept of change in speed, lead students to explore alternative perspectives?* Understanding the details of how FSD activities do or do not promote the exploration of alternative perspectives can support instructors in effective facilitation of materials that use FSDs, and inform the design of curricula that elicit higher levels of EAP.

II. THEORETICAL FRAMEWORK: SOCIO-METACOGNITION

We use the socio-metacognitive framework proposed by Borge and colleagues [11, 12]. At an individual level, metacognition involves a learner's knowledge about cognition, as well as the skills, or executive processes, that the learner deploys to monitor, control, and regulate cognition [13–15]. During collaborative learning, group members externalize their thinking through discourse and actions. The group either engages with or dismisses these externalized ideas via social interactions [12]. How the group monitors and regulates their interactions and collective learning processes is referred to as socio-metacognition. In this framework, the production of collective knowledge requires negotiation, which impacts how participants involve themselves in the collaboration. Communication patterns activate specific forms of collaboration and cognition. The framework focuses on two communication macro-patterns: collective information synthesis and collective knowledge negotiation. Each consists of three micro-patterns. Collective information synthesis occurs when members of a group share individual information, check their understanding and synthesize the information to develop shared understanding and new knowledge. Collective knowledge negotiation occurs when a group explores alternative perspectives, proposes and evaluates ideas, and engages in constructive discourse. Because FSDs propose two (or more) alternative explanations for a physical phenomenon, they (ideally) lead students to compare, analyze, and critique the alternatives. Thus, our study focuses on exploring alternative perspectives (EAP): the extent to which a group presents and discusses alternative opinions, claims, and ideas.

III. METHODS

Next Generation Physical Science and Everyday Thinking (NGP) is a research-based, student-centered curriculum, intended for pre-service K-8 teachers and consistent with the Next Generation Science Standards [16]. Core NGP activities focus on physics and physical science content, and supplementary activities explore the nature and science of learning. NGP adopts a social-constructivist model: students conduct guided experiments using simple equipment and computer simulations in small groups, punctuated by full-class discussions where groups present their findings and seek consensus. NGP targets concepts and reasoning research has identified as challenging for many physics learners [16], often through the use of fictionalized student dialogues (FSD).

This study involved physics courses using NGP at two institutions on the west coast. Both are regional, public, primarily undergraduate universities with a focus on teacher preparation. In all courses, instructors acted as facilitators, listening in on small-group discussions, responding to student questions, posing additional questions intended as formative assessment or guides to learning, and leading full-class, consensus discussions. At both institutions, the courses included the NGP units on Newton's laws and energy. This study focuses on the fictionalized student dialogue found in Unit EM: Energy-based Model for Interactions, Activity 1: Interactions and Motion (UEM-A1). UEM-A1 is the entry point for students' study of energy concepts, and students' first exposure

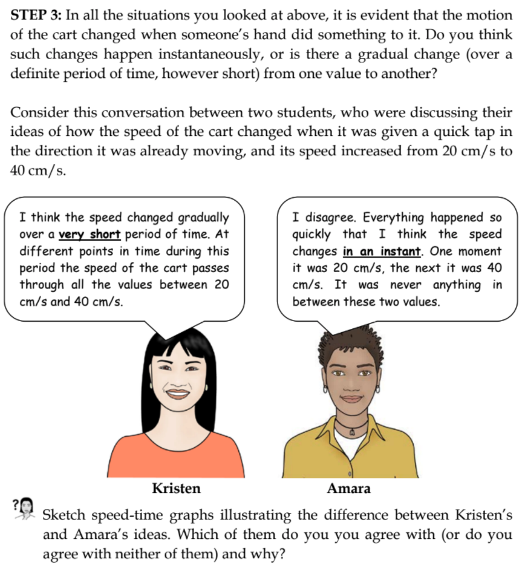

FIG. 1. Step 3 from NGP UEM-A1 includes the fictionalized student dialogue of two contrasting ideas about the concept of change in speed.

to fictionalized dialogues. The activity consists of four steps. Step 0 asks students to discuss their initial ideas about how the motion of an object is affected by an interaction. Students predict the shape of a speed-time graph for a cart that is pushed and then stopped on a low friction track. Then, in step 1, students apply quick pushes and pulls to start and stop the motion of a cart on a track, and are guided to recognize that each type of interaction has the same effect on the motion *(i.e.,* a change in speed). In step 2, students conduct experiments involving sequences of quick taps applied to an already-moving cart, and finally, in step 3, students consider the dialogue between the two fictitious students, Kristen and Amara. The dialogue presents contrasting perspectives on the nature of changes in speed of the cart during an interaction: Kristen's perspective that the speed of the cart changes gradually and continuously, taking on all intermediate values, and Amara's perspective that the speed changes instantaneously from one value to another. Students are first asked to sketch speed-time graphs illustrating the difference between Kristen's and Amara's ideas, and are then asked with which fictitious student, if either, they agree (see Figure 1).

We collected classroom video of 25 groups working through selected NGP activities during the 2021-2022 academic year. The data were collected across nine courses taught by six instructors. We have video of eight groups working through UEM-A1 that form the data corpus for this study.

After transcribing and captioning, the research team (authors) analyzed the data in two stages. In the first stage, we watched each episode multiple times together. We independently coded the transcripts for occurrences of the micro-communication patterns from the Borge's framework, and then discussed our codes to reach a consensus [17]. After coding all eight episodes, we rated each group on a three-level scale of *high, moderate, low* according to the depth and quality of the group's exploration of the alternative perspectives (EAP) on change in speed presented by the fictitious students Kristen and Amara. Below, in Results, we describe further our rationale for assigning specific ratings.

In the second stage, the research team selected three groups, one from each level, to create contrasting case studies. For each case study, two researchers independently drafted descriptive narratives. These narratives were intended to trace the intellectual steps taken by the group in making sense of, and evaluating, the perspectives of Kristen and Amara. Researchers stayed as close as possible to student utterances when drafting the narratives. All three researchers then discussed and compared the two narratives, identifying and resolving salient differences. Based on this synthesis, we collaboratively analyzed the extent to which the group engaged in EAP. The next section presents these analyses.

IV. RESULTS

In this section, we describe three case studies we classified as representing high, low, and moderate-level EAP based on the extent to which they discussed both ideas, and identify themes within each. In the Discussion, we present a comparative analysis. Quotes are lightly edited for readability.

Case Study 1: High-level exploration of alternative perspectives. In this case study, three students, Alma, Barbara, and Cathy, spend just over six minutes discussing the instantaneous change perspective of Amara and the gradual change perspective of Kristen.

The group leads by agreeing with one of the two perspectives. Alma initiates the discussion by endorsing the gradual change perspective ("I think it's Kristen"). Cathy immediately confirms this by disagreeing with the contrasting, instantaneous change perspective ("it's not at an instant"). As a group, the students then explore each perspective in detail, first by applying each perspective to a familiar real-world phenomenon (driving a car), and then by drawing speed-time graphs for each perspective.

Alma introduces the real-world context, which is then immediately taken up by both Cathy and Barbara:

> *Alma: When you are driving a car you're not going to press on the gas pedal when you are going 28 and [go] immediately to 56 without even going through 29.*
>
> *Cathy: Is that even possible for any type of circumstance, for it to just be. . .*
>
> *Barbara: Not like instantly. . . even if you are in a fast car it goes gradually.*

In this exchange, Alma relates her experience that the speed of a car (presumably through observing the speedometer) does not change from an initial value to a final value without passing through an (arbitrary) intermediate value. This serves as a counter-factual argument to attack the validity of the instantaneous change perspective. Cathy takes up Alma's real-world example by generalizing it ("Is that even possible for any type of circumstance?"). Barbara then continues by offering validation of the alternative perspective ("Even if you are in a fast car, it [the speed] goes gradually"). In this first part of the case study, which lasts about 80 seconds and involves 28 talk turns that include all members, the group explores the implications of the contrasting perspectives presented in the fictionalized dialogue, rather than only validating the perspective with which they initially expressed agreement. The group compares the implications of Amara's instantaneous change perspective with their own real-world experience, and the recognition of inconsistency leads them to reject Amara's perspective.

In the second part of Case Study 1, the group constructs the two speed-time graphs. The group explores both graphs in detail, rather than only discussing the gradual perspective that they agree with. The students start by individually sketching graphs for each perspective, and then compare their graphs to check for agreement. The students discuss details of the shape of each graph, including how underlying perspectives on change relates to the shape of the graph. For example, when discussing the graph Amara would draw, Barbara explains "So one moment it [the speed of the cart] was at 20 and next - so like it would be... there wouldn't even be a line 'cuz it's not gradual, right?", to which Alma agrees.

We categorize Case Study 1 as high level EAP due to the sustained consideration of two contrasting perspectives on change in speed. Although the group has already reached a consensus on which perspective makes more sense to them, they explore each perspective in detail.

Case Study 2: Low-level exploration of alternative perspectives. Our low EAP group consists of three students, Kate, Amy, and Jose. They spend three minutes on the FSD, one minute agreeing with Amara's instantaneous idea and two minutes drawing the speed-time graphs.

The group discussion starts after Amy reads the question aloud, and then immediately shares that she thinks the speed changes at an instant based on her experience pushing the cart on the track ("When we pushed, there was not really change and it was just going straight, probably the only one that was changed was when we put our finger in that there was instant change"). Jose agrees with her, pointing out that this is aligned with Amara's idea, and Kate adds that the speed change was "very fast."

This discussion ends when Amy reminds the group to draw the speed-time graph ("Now we have to sketch the speed-time graphs"). After the students have all independently drawn their graphs, Jose checks in with his partners. While holding his paper up to show his graphs, he explains how he drew them based on the timescale. He says, "I think Kristen's might take longer, so it'd be more like that, a little flatter, and then Amara, since it's at an instant, like how we drew ours, it'd be more like right away because it takes less time, and that takes longer ... because it took less time for Amara and that's what she thinks and then it took more time for Kristen's to gain speed." Amy and Kate agree with Jose's graphs and explanations ("I think that makes sense").

We categorized Case Study 2 as low EAP due to the lack of interrogation of the gradual change idea. After endorsing Amara's instantaneous change idea, the group does not explore Kristen's alternative perspective of gradual change. Although the students agree the change in speed is instantaneous, Kate seems to raise the possibility of Kristen's gradual change idea by describing the change as "very fast." However, the group does not discuss what the gradual change would look like or why a gradual change might be correct. The prompt in the activity seems to force the students to consider both perspectives, and they describe differences between the two graphs. However, the students do not interrogate Kristen's idea of gradual change in speed, or discuss in detail how or why that idea does or does not make sense to them. At no point does the group engage with the abstract notion of an instant in time, or consider differences that arise from analyzing the motion at shorter or longer timescales.

Case Study 3: Moderate-level exploration of alternative perspectives. This group of four students, Cami, Penny, Huy, and Brian, explores alternative perspectives at an intermediate level, between that of Case Studies 1 and 2. They spend four and a half minutes considering the fictionalized dialogue. In the first two minutes, they agree with Kristen's gradual change idea and consider the possibility that Amara's instantaneous idea could be relevant depending on the choice of timescale. For the remaining time, they draw the speed-time graph for a gradual change.

After reading the prompts silently, Penny initiates discussion when she asks her partners if they believe the speed increases gradually, over a short period of time, or changes in an instant. Penny shares her experience of perceiving the speed change as instantaneous, but also seems to consider the possibility that the change is gradual, if timescale is accounted for ("visually it was an instant but technically time-wise..."). Brian states, without explanation, that he thinks the speed changes gradually, and not in an instant ("it would be like a gradual just like very quickly gradual, but I don't think it's like an instant though"). In response, Penny elaborates on her idea of timescale, "I guess it also depends on how much within those 4 seconds how much of time are you counting, like tenths of a second, hundredths of a second..." She then turns to Cami and points to the blank graph on the laptop screen to explain what the graph would look like for a gradual change when considering smaller time intervals. This phase of the discussion ends when Huy asks, "Who did you agree with?" For the remainder of the episode, the group considers how to draw a speed-time graph for a gradual change that occurs over a four-second time interval.

We categorized Case Study 3 as moderate level EAP because the students discuss, in some detail, both the gradual and instantaneous change perspectives. The students do not explore why the instantaneous perspective is flawed, but do discuss how a gradual change could look like an instantaneous change if the time intervals on the graph are large enough. Huy's prompt to decide which fictitious student they agree with seems to curtail further exploration; the students quickly settle on the idea of a gradual change, and spend their remaining time working on that graph.

V. DISCUSSION AND CONCLUSION

The activity involving the FSD between Amara and Kristen elicited high-level EAP in two groups, moderate EAP in three groups, and low EAP in three groups. All groups discussed both the gradual change perspective of Kristen and the instantaneous change perspective of Amara, consistent with the activity prompts, which asked students to sketch the speed-time graphs for both perspectives. We speculate this FSD led to more EAP than an activity that presents only a single, normative perspective linked closely to the correct answer to a specific question or task. Such an activity, with a relatively less open-ended format, would seem likely to lead most students to consider only a single solution. Future research could investigate the extent to which FSDs, as a form of instruction, do in fact enhance student exploration of alternative perspectives.

This activity's explicit directions to produce graphs, in tandem with students seeking to identify the "right" idea, may have interfered with student engagement with the two perspectives. In comparison to the moderate and low EAP groups, students in the two high EAP groups engaged in longer discussion of the two perspectives before shifting attention to the graphs. In the low and moderate EAP case studies, the conversations shifted relatively quickly from more open-ended consideration of the contrasting perspectives to more directed efforts to agree on a correct answer. For example, Huy asks "Who do you agree with?" in the moderate EAP case study, and Amy states "Now we have to sketch the speed time graph" in the low EAP case study.

All three case study groups discussed timescale. The low and moderate EAP groups did so when drawing their graphs. The moderate EAP group (Case Study 3) focused on the scale on the time axis for the graphs, while the low EAP group (Case Study 2) focused on the length of time over which the change occurred, with less focus on the scale of the time axis. Regardless of which perspective a group endorsed, groups noted a perception that the speed of the cart changes "immediately" when the finger taps it. The high EAP group's discussion focused on the real-world example they had generated: driving a car. We speculate that this example was motivated in part because the changes in speed of a car occur on a more perceptible timescale than the changes in speed of a lab cart that is given a quick tap while moving on a track. The high EAP group focused on shorter lengths of time, 0.1 and 0.01 seconds, over which the car's speed changed. We infer that they recognized the differences in time scale between the car and the cart contexts, and examined shorter time scales as a way to translate from their real-world experience of the car to the laboratory experience of the cart. Contrasting the familiar example of the car with the more "physics-y" example of the cart may have supported the high EAP students in abstract thinking about timescale and the nature of changes in speed. Investigation of student exploration of alternative perspectives in specific FSD activities can identify productive resources, such as the use of driving a car as a real-world example of how speed changes over time, that are activated in groups with high-level EAP. These resources could then be available to instructors as tools to increase student consideration of alternative perspectives.

The high EAP group of Case Study 1 engaged in the productive but uncommon practice [18] of disconfirming an alternative explanation. They could, however, have engaged in even further exploration of the two perspectives. For example, the group could have generated novel examples of changes that are instantaneous in nature (e.g., the change in the amount of a bank account when a paycheck is deposited, or the change in the energy of an atom when a photon is emitted). Questions that are more esoteric, but still meaningful (e.g., whether falling in love occurs gradually or suddenly) might also foster higher levels of exploration of alternative physics explanations and perspectives. Supplementing this FSD with an activity to engage students in contrasting cases of instantaneous and gradual changes beyond speed could help students to engage more with the alternative perspectives. Instructors could use such strategies across the modules in the NGP curriculum.

Many PER-based materials use FSDs to engage students with contrasting perspectives [1–3]. In the FSD studied here, most groups did engage in moderate to high levels of exploring alternative perspectives. Exploring alternative perspectives, however, is only one of many communication patterns that may arise in a social learning environment. Further study can investigate whether FSDs foster other productive learning behaviors aligned with the socio-metacognitive framework. This framework provides a structure for investigating how FSDs support student collaboration for synthesizing information and negotiating new knowledge in equitable and constructive discourse. Further work on FSDs can identify what effects they have on learning dynamics in small group environments and how to design and integrate them into curricula to maximize their benefits.

ACKNOWLEDGEMENTS

This material is based upon work supported by the NSF, DUE-2021547 and DUE-2021307. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the NSF. We also thank Carolina Alvarado.

[1] L. C. McDermott, P. S. Shaffer, *et al.*, *Tutorials in introductory physics* (Prentice Hall Upper Saddle River, NJ, 2002).

[2] F. Goldberg, S. Robinson, E. Price, D. Harlow, J. Andrew, and M. McKean, Next generation physical science and everday thinking, Greenwich, CT: Activate Learning (2018).

[3] C. J. Hieggelke, S. E. Kanim, T. L. O'Kuma, and D. P. Maloney, *TIPERs: Sensemaking tasks for introductory physics* (Pearson, 2015).

[4] N. R. Council *et al.*, Next generation science standards: For states, by states, (2013).

[5] L. C. McDermott, Oersted medal lecture 2001:âphysics education researchâthe key to student learningâ, American Journal of Physics **69**, 1127 (2001).

[6] A. F. Heckler and A. M. Bogdan, Reasoning with alternative explanations in physics: The cognitive accessibility rule, Physical Review Physics Education Research **14**, 010120 (2018).

[7] M. Kryjevskaia, P. R. Heron, and A. F. Heckler, Intuitive or rational? students and experts need to be both, Physics Today **74**, 28 (2021).

[8] N. D. Finkelstein and S. J. Pollock, Replicating and understanding successful innovations: Implementing tutorials in introductory physics, Physical Review Special Topics-Physics Education Research **1**, 010101 (2005).

[9] T. Iiskala, M. Vauras, E. Lehtinen, and P. Salonen, Socially shared metacognition of dyads of pupils in collaborative mathematical problem-solving processes, Learning and instruction **21**, 379 (2011).

[10] S. Volet, M. Summers, and J. Thurman, High-level coregulation in collaborative learning: How does it emerge and how is it sustained?, Learning and Instruction **19**, 128 (2009).

[11] M. Borge, Y. S. Ong, and C. P. Rosé, Learning to monitor and regulate collective thinking processes, International Journal of Computer-Supported Collaborative Learning **13**, 61 (2018).

[12] M. Borge and B. White, Toward the development of sociometacognitive expertise: An approach to developing collaborative competence, Cognition and Instruction **34**, 323 (2016), https://doi.org/10.1080/07370008.2016.1215722.

[13] A. L. Brown, Metacognition, executive control, self-regulation, and other more mysterious mechanisms, Metacognition, motivation, and understanding , 65 (1987).

[14] J. E. Jacobs and S. G. Paris, Children's metacognition about reading: Issues in definition, measurement, and instruction, Educational psychologist **22**, 255 (1987).

[15] G. Schraw, Promoting general metacognitive awareness, Instructional science **26**, 113 (1998).

[16] F. Goldberg, V. Otero, and S. Robinson, Design principles for effective physics instruction: A case from physics and everyday thinking, American Journal of Physics **78**, 1265 (2010).

[17] S. J. Derry, R. D. Pea, B. Barron, R. A. Engle, F. Erickson, R. Goldman, R. Hall, T. Koschmann, J. L. Lemke, M. G. Sherin, *et al.*, Conducting video research in the learning sciences: Guidance on selection, analysis, technology, and ethics, The journal of the learning sciences **19**, 3 (2010).

[18] R. S. Nickerson, Confirmation bias: A ubiquitous phenomenon in many guises, Review of general psychology **2**, 175 (1998).