Merging Learning Progressions and Feedback Principles to Guide AI Support for Student Models and Explanations in Physical Sciences

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Background

Science education should provide opportunities for students to engage in complex reasoning about compelling phenomena. When these opportunities are integrated in classroom settings with fidelity, students frequently construct models and explanations. However, scoring and providing effective feedback for these artifacts is time-consuming and puts a lot of pressure on teachers. This project aims to support teachers and learners by developing an automatic scoring and feedback-generating system in the context of an NGSS-aligned curriculum called *Interactions*, which focuses on physical sciences.

How can principles of effective feedback be used to structure feedback statements that support learning through cognitive engagement?

Research Aim

Establish feedback principles that achieve the following:

1. Leverage previous literature regarding effective feedback in, primarily, the cognitive domain, and supported by literature regarding student motivation and affect
2. Align with the context of the *Interactions* curriculum and learning progression levels
3. Guide an AI system to generate effective, meaningful feedback

Table 1. Levels of NGSS LPs for Electrical Interactions[1]

Level 3: Models and explanations represent causal relationships that integrate ideas of Energy and Coulombic interactions.
Level 2: Models and explanations represent causal relationships that use, but do not integrate the ideas of Energy and/or Coulombic interactions with few inaccuracies.
Level 1: Models and explanations represent partially causal relationships that use ideas of Coulombic interactions or Energy with inaccurate/incomplete ideas.
Level 0: Models and explanations that don't represent causal relationships, don't use Coulomb Law and/or Energy or include significantly incomplete ideas.

Principles development process

Theoretical contributions

LP levels and ECD arguments

Frequent, iterative group (4-6 researchers) discussions focused on interpreting student responses and generating meaningful feedback.

Literature review

Examining effective feedback design and processes [2, 3, 4, 5]

- *Student cognition and learning*
- *Student motivation and affect*

Data analysis

Teacher and expert interviews

Analysis of teacher and science-education expert perspectives on feedback

in progress

Student interviews

Analysis of high school student perspectives on feedback

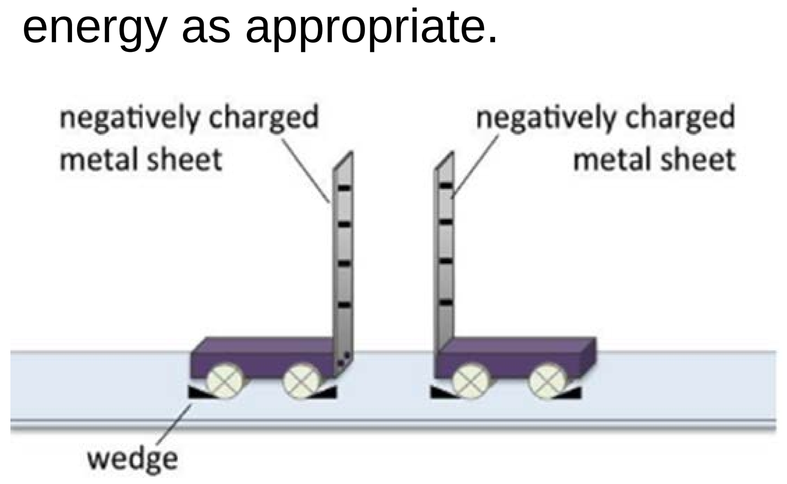
in progress

Theoretical contributions and data analysis inform & validate principles

Feedback Principles

Principle	Description
Encouraging & motivational	Acknowledging what the student has done well, while avoiding vague praise. Address inaccuracies in a way that encourages further investigation/learning.[3, 4]
Constructive & actionable	Building from student response, serving as a ***scaffold***. Acknowledge and build from existing ideas to support incorporation of other ideas relevant to the scenario. Use *action words* so that students know what they need to do next.[2, 3, 4, 5]
Comprehensible & clear	Constructing feedback statements that are readily usable for students. Can they make sense of the feedback? [9th-grade reading level] [3, 4, 5]
Aligned with learning progression	Supporting students to focus on relevant science. Acknowledge relevant ideas students use and use scaffolding strategies to help them move up LP, without providing too much information.[1]

Predict which direction they will move and when they will stop. Use ideas about forces and energy as appropriate.



Example student response:
The carts will move away from each other. If we know that like charges repel, as learned in the simulator. The carts will start out with a strong force between the two and accelerate away from each other. The farther away they get, the more the force weakens. – Student N1291

Example feedback:
You accurately predicted that the carts will move away from each other due to like charges repelling, and that the force weakens as they get farther away. [Encouraging & motivational] *Next, think about the energy involved. How will the energy of the system change as the carts move further away? Why does this change in energy occur?* [Constructive & actionable; Aligned with LP]

Initial Findings

Question	Student Initial Justification	Feedback Statement	Student Revised Justification
What is different about Scenario A and Scenario B? Justify your answer.	*The difference between the 2 scenarios are the rod is charged when it hits the metal ball on the second scenario because the charges repel the foil leaves.*	Note that in both scenarios A and B, the rod is charged and the leaves spread apart. Let's think about how the charged rod is different in scenario A and B. How does this difference cause the leaves to move further apart in scenario B compared to scenario A?	*The first scenario has a less strong charge making the leaves not repel as much. in the second scenario the rod has a stronger charge going into the leaves making them repel more*
LP level	level 0		level 2
Analysis Notes	Indicates charge transfer, but incorrectly states the rod is charged in only one scenario	Student notes feedback is clear & motivating: *"It was easy to read and it showed me a lot of what I did wrong…It's all helpful, it makes me happy to change."*	Relates the amount of charge to the magnitude of the repulsive electric force in both scenarios

Initial findings from student interviews

- Feedback improves quality of response but does not always promote progression at single time point.
- Students report that feedback statements align with principles:
  - All students were able to correctly understand the feedback (comprehensible and clear).
  - Students were able to quickly revise their responses based on feedback (constructive and actionable).
  - Students felt the feedback was relevant to their responses and guided them in improving responses (alignment with learning progression).

Ongoing efforts

Training an AI system to score student responses and provide tailored feedback guided by these principles and LP-focused priorities.

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