Innovate to Mitigate: Microgenesis of student design and rationale in a crowdsourcing competition to mitigate global warming

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Project Overview

The Environmental Innovation Challenges (EIC) project investigates learning as 8th-12th grade students, supported by social media and crowdsourcing, design, and test innovations focused on reducing carbon emissions. Our hypothesis is that *competitive challenges supported by social media and crowdsourcing will engage a diverse array of students in sustained and meaningful scientific inquiry*. We anticipate that team members will engage with each other and other teams, using such science practices as modeling, experimentation, error-analysis, argumentation, representation and communication. In this poster, we present a case study that shows crowd-sourcing impact on the formulation of a student project.

In an exploratory project (NSF 1316225) students reported significant gains in knowledge about climate change science, the science of their particular project, the nature of scientific research, and some science practices, including the communication of research (Puttick et al., 2017). A case study provided insight into group learning, and the development of group processes and roles (Drayton and Puttick, 2018).

This paper presents an account of microgenesis of learning of STEM concepts and practices supported by a web-mediated community of practice. The paper addresses *4 research questions*: (i) What evidence is there that crowd sourcing led to changes in students' designs and rationales? What kinds of changes are seen? (ii) How are these changes related to students' use of ideas generated in dialogue? (iii) To what extent does the composition of the community contribute to the dialogue or to students' uptake of these inputs? (iv) To what extent do the data allow investigation of microgenesis of students' design and rationales?

Methods

Participants. For this paper, we analyze the data generated by three I2M (Innovate to Mitigate) teams during the 2020-2021 competition: "LaGrazia" (three 8th graders), "Pedalpushers" (two high school students), and "Pranav No-Till " (one high school student working alone).

Data sources. Since abstracts scaffold the whole investigation, students are given a rubric that identifies elements to address (see suppl. pdf). Teams post an abstract describing their proposal to the project's EdModo page. All participating students are invited to post questions and comments on each abstract. Once student dialog has ended, TERC scientists may also post comments and questions. Teams have 2 weeks to consider comments and revise. Once revised abstracts are posted, the teams conduct their project over the next 3 months. The data in this case study include:

- The team's initial abstract
- All discussion posts from other students and scientists, and the team's responses
- The revised abstract
- Final paper and discussions

Analysis. Two researchers consensus-coded each document for technical/science content, methodologies, design elements, "innovativeness," rationale for choices being made, and evidence adduced. Types of questions raised were noted, e.g., technical, design, request for clarification. We used a 4-part coding scheme (Sandoval & Millwood, 2008) to characterize categories of argument in teams' rationales:

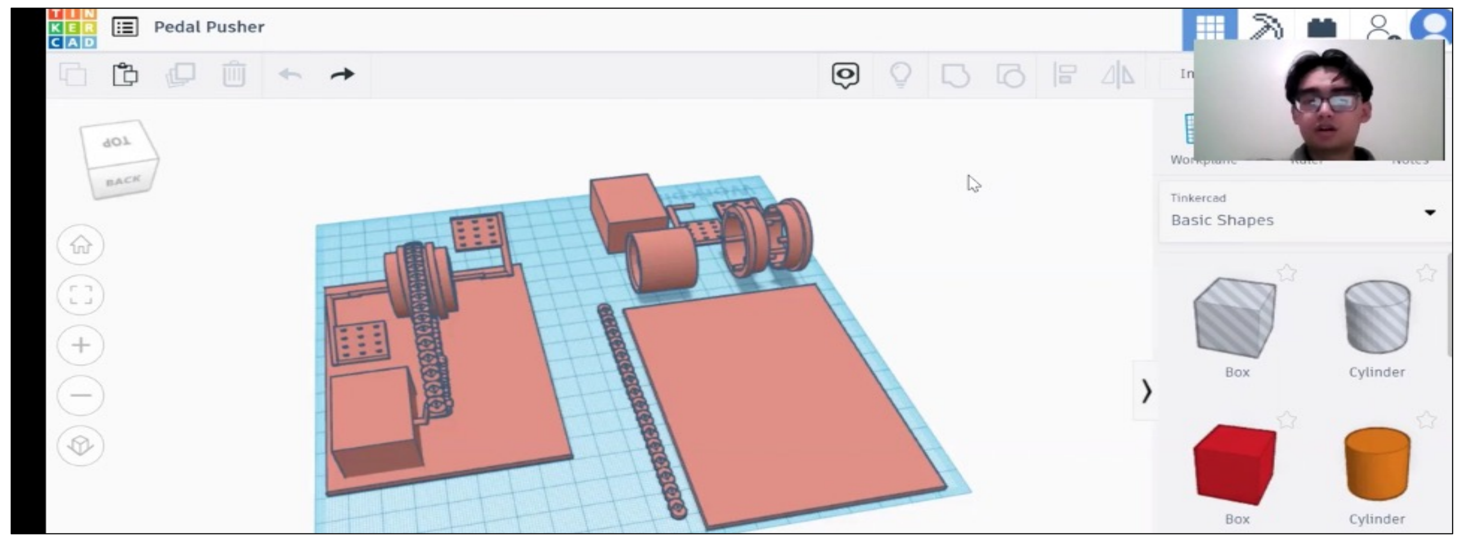
Category	Meaning
Authority	Explicitly cites an authority, e.g., teacher, text, article, Web
Causal	Argument relies upon some explanatory theory or concept
Empirical	Argument is based on empirical data, or absence thereof
Factual	Asserts the claim as fact.

Coded data were discussed by the research team. After coding was stable, a researcher wrote an interpretive research narrative, addressing the research question based on the data. It was read and discussed by the whole research team to test inferences, identify issues requiring further analysis, and maximize the value of the data.

Findings

Case 1: Pedalpushers. This team designed a pedal mechanism in which students generate sufficient energy to meet their classroom electricity needs. Their final paper reflects the impact of the questions they were asked; they included more information derived from studies cited in the literature (*authority,* 3 coded instances) and, from this, made quantitative comparisons between their pedal-driven system and other green electricity sources. These, and causal claims derived from them (3 occurrences), reflect a richer theoretical rationale. *Rhetoric* increased; they used repetition to frame the elements of their design and rationale in relation to the *goal* of their proposed invention. They repeated the key advantages of the design, emphasizing potential scaling effects, and reiterated the relation of their design to the need to mitigate CO_2 emissions. They invited the reader to imagine the system in operation, thus using their present design as a way of prototyping a future. They thus bookended their argument by pairing what we may call the proximal goal of their proposal with a distal or overarching goal, mitigating global climate change.

Case 2: La Grazia. La Grazia designed and tested a solar oven constructed from recycled materials. Over the course of developing their project, they deepened their rationale elements by increasing *causal* (from 2 to 4) and *authority* statements (from 0 to 10). Moreover, they reported data from a series of *empirical* trials of two different instantiations of their solar cooker design (6 instances). Isolation of students owing to COVID had the benefit of making experimental replication possible. They reported all data, although these were inconclusive. Moreover, the number of *rhetorical* elements also increased slightly (3 instances). The team's attention to *empirical* and *causal* rationale elements continued through the discussion of final products on-line. The changes were noted by the judges. For example, one judge commented "I liked that you cited several references and provided the bibliography, and that you stated hypotheses for your proposed innovation." Finally, the team responded directly and appropriately to open questions or unsolved problems raised by judges and other participants.



Screenshot from Pedalpushers final video showing early design idea.

Case 3: Pranav No-Till. Pranav No-till proposed a novel combination of no-till agriculture with incentives for farmers to shift to these new methods. The final paper reflected the extensive discourse about his abstract that had occurred; the author deployed a coherent rhetorical strategy to elaborate on points raised in the discussion. The rhetorical elements (4 instances in 9 paragraphs) introduced affective notes (e.g., "no-till agriculture is environmentally friendly, and economical for farmers, too"), or motivational/moral notes. Other elements included:
a. Rationale elements. The paper shows a consistent use of *authority* (18 instances, coded in all 9 paragraphs), along with *factual* assertions (5 instances), *empirical* statements (4 instances), and *causal* statements (5 instances).
b. Goal or design elements. The overall aim is reiterated frequently in conjunction with rationale elements (in 6 paragraphs).
c. Innovation, advantage, scaling. The potential contribution to CO_2 mitigation of a widespread adoption of no-till agriculture is reiterated in every paragraph, either explicitly connected with rationale or goal/design elements, or juxtaposed.
Most striking, this repeated use of the "goal/design/rationale/benefits/rhetorical" elements in posing a problem and advocating for a potential, innovative solution throughout was itself an effective rhetorical performance.

Conclusions

RQ1. Changes in students' designs and rationales. The three cases all show increases in *rationale* statements in response to comments. *Empirical*, *causal*, and *authority* statements are more salient in the final papers, and in the case of the Pedalpushers and Pranav No-Till, they became more important in a second, revised abstract, even before the paper was written. La Grazia showed little change in this regard in their second abstract, but in fact they dramatically increased their use of factual rationale statements. The Pedalpushers increased the use of empirical rationale statements in both their second abstract and their final paper, but many of these were statements of what kinds of data would be collected in a full development project. All teams also showed a range of increases in *rhetorical* elements.

RQ2. Students' use of ideas generated in dialogue. RQ3. Influence of community composition. ***Students*** asked questions primarily about details of design, implementation, and impact, and about proposed or suggested advantages. ***Scientists*** sought clarification of *causal* rationales for elements of the design, and its connection to CO_2, and also probed for empirical evidence about arguments students made in support of claims about how innovative their designs were.

Taken together, community input had a significant impact on the way the teams thought about most aspects of their designs and rationales; the diversity of the community composition made an important contribution. The scientists' emphasis on causal and empirical rationale elements, in contrast to students' primary focus on design, is evident. But other differences also came into play, e.g., when a student discussant raised the possibility that the Pedalpushers' design might benefit kids with ADHD. We see that community diversity benefits STEM because it brings richness of experience, expertise and other kinds of knowledge.

RQ4. Investigation of microgenesis. We can claim only suggestive evidence about the usefulness of this medium for understanding student argumentation and design through microgenetic studies. The narratives presented show evidence of growth in students' understanding of the processes of design and argumentation. Stimulated by contributions from the community of practice appeared to result in arguments that were more coherent, conceptually consistent, and rhetorically effective. However, the *Innovate to Mitigate* environment as implemented has some drawbacks as a medium for microgenetic studies: (1) Insufficient density of communication since students only share and discuss their work twice during the competition. (2) Inaccessibility of some data, owing to students' use of other media (e.g., texts or phone calls) for within-team conversations.

We propose in future research to co-design a study with one or two teams to address these issues. This will better enable researchers to track the interplay of student thinking (externalized in documents and designs), peer interaction, and development of understanding in the context of a student-chosen task that requires factual, conceptual, and instrumental learning, and its representation in narrative and in argument.

For full paper see https://www.terc.edu/profiles/brian-drayton/

References

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