Argument Construction to Drive Inquiry

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Abstract. We investigate how students use an online notebook embedded in a web-based inquiry environment to develop a coherent argument and identify revisions to the technology to improve outcomes. Students use the notebook to record their investigations and develop a written argument concerning gasoline combustion and climate change. They write a letter to a local political representative to explain the problem of suggest an alternative fuel to mitigate greenhouse gas accumulation. Students are guided to incorporate evidence from the curriculum into the notebook, including data from computational models. Two teachers and 279 students participated. Pretests, embedded assessments, post tests student reports and classroom observations were collected. Findings suggest that students advanced in understanding of science successfully incorporated everyday ideas into the notebook. They had difficulty incorporating relevant evidence from the computational model or using the evidence to revise their initial ideas. We discuss opportunities provided by the tool and areas for improvement.

Keywords: inquiry, argumentation, science practices, knowledge integration, inquiry environment

PURPOSE

We evaluate the affordances of a an online notebook, a web tool incorporated into the Web-Based Inquiry Science Environment (WISE, http://wise.berkeley.edu), to drive inquiry by guiding students to generate a multimedia argument that incorporates content from online resources. Notebooks can support inquiry (Carey et al, 1989). Developing an argument engages students in critical scientific practices, including conjecturing, gathering evidence, distinguishing among viewpoints, identifying gaps, and refining their perspective (Ford, 2012). In addition, by framing their argument around a socially relevant topic (climate change) and audience (a local politician) this investigation can help students connect their ideas gathered from both inside and outside the classroom.

We use the knowledge integration (KI) framework to design the curriculum, the notebook, and the pre/posttest assessments. Knowledge integration (Linn & Eylon, 2011) is a constructivist view that synthesizes research on learning and instruction in inquiry science. It emphasizes that students hold a wide repertoire of ideas about a given science topic. These ideas are often inconsistent, and in some cases even contradictory. Argument development tools, such as the notebook, give students opportunities to use evidence, distinguish among their ideas and those presented by instruction, and refine their perspective.

METHODS

Participants and Curriculum

Two hundred and seventy-nine 8th grade students in two teachers' classrooms in one moderately diverse public middle school participated. Students used the 7-10 day *Chemical Reactions* WISE project to investigate the role of gasoline combustion and alternative fuel chemical reactions in climate change.

Notebook

The notebook was designed to prioritize argument development as the driver of an investigation. The notebook allows students to capture evidence from diverse activities across a web-based inquiry project and integrate the evidence with text in an evolving argument. Within the curriculum, students can send multimedia content to the notebook by clicking on the relevant image or text, and then easily navigate to the notebook. The notebook space offers rich text editing tools to annotate and organize collected multimedia [Fig 1]. Notably, students can capture snapshots from a computational model to provide evidence for chemical phenomena. In the Chemical Reactions project, students use the notebook to write a letter to their local political representative to advocate for mitigation of greenhouse gas emissions. We included editable headers with sub-questions in the notebook space [e.g. Introduction, Problem, Plan, Conclusion] to support students' argument organization. We provided prompts throughout the Chemical Reactions project to highlight appropriate evidence that students could select to support their argument.

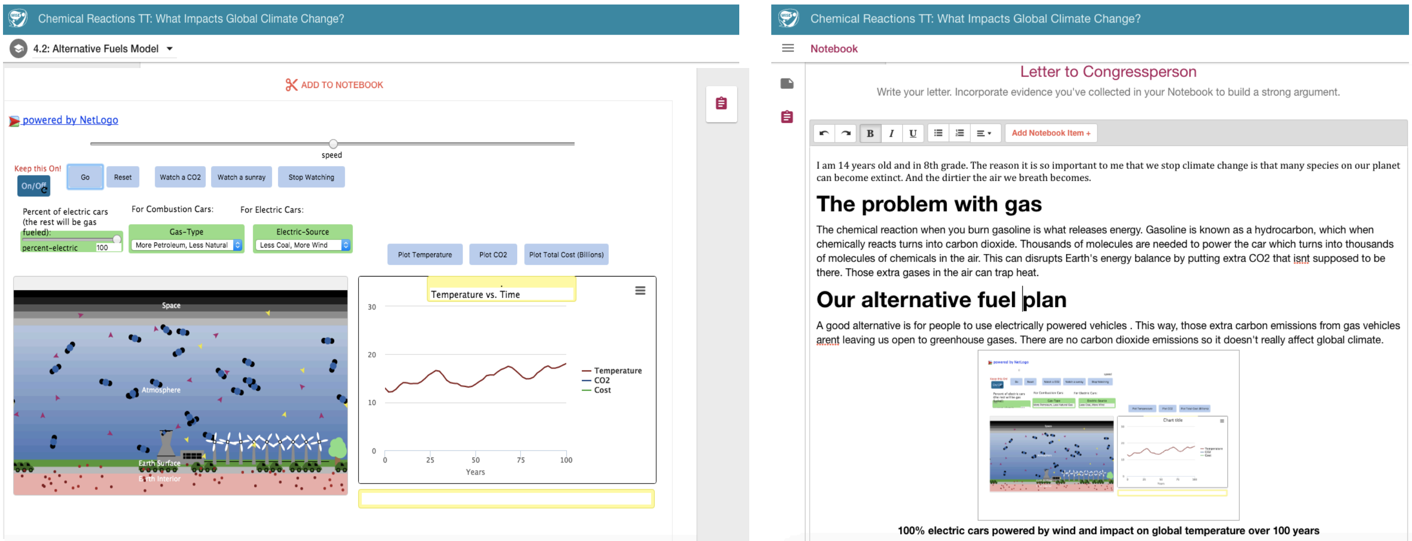


Figure 1. Chemical Reactions inquiry curriculum (left) and notebook (right) within the WISE environment. At the current inquiry step (left) students interact with a computational model of fuel effects on climate. Students can send screenshots of the model to the notebook (right), where they can incorporate the image into their argument.

Data Sources and Analysis

We scored students' letters, and their written responses on three pre/post test items. The pre and post test included three explanation items aligned with the science standards for physical science, grade 7. We scored items using 5-point knowledge integration scoring rubrics that reward students for making accurate evidence-based connections among ideas (Liu, Lee, Hofstetter, & Linn, 2008). All data was scored first by two human-raters until we reached 95% inter-rater reliability. One rater then continued the scoring. We gathered written student reflections and conducted classroom observations to clarify how students used the notebook.

RESULTS

Pre/Post Test. Results showed that students gained integrated understanding of chemical reactions and their role in climate change. [Coal Factory: Gain=.21, $t(96)=2.31$, $p=.02$; Friend Buying Car: Gain=.34, $t(250)=5.6$, $p=.00$; Chem Reaction Drawing: Gain=.34, $p=.00$]. This suggests that argument development as a driver of inquiry can strengthen content understanding.

Letters to Congress. Students explained the problem of gasoline combustion in climate change (Problem: Mean KI score=3.33, SD=1.17). Students conneccted ideas about the reactants and products in a gasoline combustion reaction [67%], or ideas about carbon dioxide production and global temperature change [46%] to explain the problem. A minority of students explained how the carbon dioxide interacts with infrared to cause climate change [24%]. Students struggled to make comparisons among alternative fuels to mitigate the problem. Most students reported evidence without linking it to a claim, or, generated normative and non-normative ideas as evidence [Table 2]. When students made a comparison (54%), they were most likely to compare alternative fuels based on carbon dioxide emissions. Few students (14%) weighed the trade-offs of all outcome variables provided in the computer model: change in cost, global temperature and carbon dioxide emissions over 100 years. Some students also struggled to connect their problem statement to their proposed solution (23%). After describing the role of gasoline combustion in climate change, the students often relied on their initial ideas for a solution to climate change (e.g. stop littering) rather than using evidence from the model.

When developng their argument over the 10 day unit, students assumed an active role in their learning. The majority of students (84%) explained how writing an argument to their Congressperson helped them clarify or advance their thinking, e.g. «it also helped me understand the concept more because I had to explain to someone else». Notably, 14% of students also identified and incorporated pictures from outside of the WISE project to strengthen their argument. Students who reported the activity unhelpful (16%) noted difficulties with the interface and integration of the activity with the investigation.

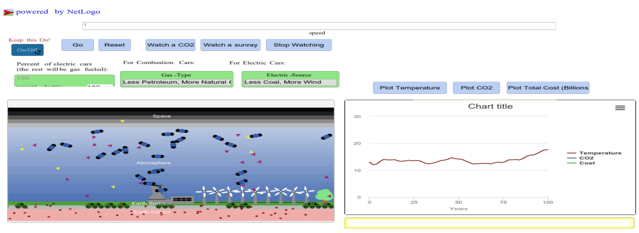
Table 1. Examples of Student Use of Evidence from Computational Models to Compare Alternative Solutions

<table>
<tr><th>Description</th><th>Examples</th></tr>
<tr><td>Combines normative and non-normative evidence to compare solutions

Data table does not give clear evidence for solution</td><td>A good alternative to gasoline is natural gas. It doesn't cost too much, it adds a lot less heat into the atmosphere, and it adds less carbon dioxide to the air than gasoline. Other people might propose to use wind or just stick with the methane gas, but those aren't the proper solution. Wind costs a lot more to manufacture than gas and electricity. We already know that methane increases global temperature and the amount of carbon dioxide in the atmosphere.
<table>
<tr><th>Trial</th><th>% Elec</th><th>Gas Type</th><th>Elec Source</th><th>Temp</th><th>CO_2</th><th>Cost</th></tr>
<tr><td>3</td><td>50</td><td>Petrol > Nat</td><td>Coal < Wind</td><td>27.8</td><td>73</td><td>21.7</td></tr>
<tr><td>4</td><td>50</td><td>Petrol = Nat</td><td>Coal > Wind</td><td>31.1</td><td>94</td><td>23.8</td></tr>
<tr><td>5</td><td>50</td><td>Petrol = Nat</td><td>Coal = Wind</td><td>21.9</td><td>79</td><td>24.6</td></tr>
<tr><td>6</td><td>50</td><td>Petrol = Nat</td><td>Coal < Wind</td><td>23.5</td><td>67</td><td>24.4</td></tr>
<tr><td>7</td><td>50</td><td>Petrol < Nat</td><td>Coal > Wind</td><td>20.5</td><td>86</td><td>26.4</td></tr>
<tr><td>8</td><td>50</td><td>Petrol < Nat</td><td>Coal = Wind</td><td>25.4</td><td>70</td><td>27.3</td></tr>
<tr><td>9</td><td>50</td><td>Petrol < Nat</td><td>Coal < Wind</td><td>21.8</td><td>58</td><td>27</td></tr>
</table></td></tr>
<tr><td>Uses normative evidence to compare solutions

Image of model state gives visual evidence to support solution</td><td>The problem with cars comes not from the cars themselves, but rather from the fuel they use. If we can find and alternative fuel, we could help alleviate this. A popular alternate fuel that's already in use is electricity. While this sounds like an easy solution in theory, producing electricity creates tons of pollution as coal is generally burned to create electricity. However, I've recently heard that using power from windmills could be a good alternative...The biggest problem with this method, however, is that it costs a huge amount of money to establish the windmills. Yet, after that money is spent, it has a really low upkeep cost.

A simulation was run to see how much CO_2 would be in the atmosphere after a century of using wind-powered electric cars. While there's still CO_2 from the factory, it rises very slowly and is much more manageable than our current CO_2 emissions.


</td></tr>
</table>

CONCLUSIONS AND IMPLICATIONS

Overall students were able to use the notebook tool to develop an argument and gain understanding of standards-aligned science concepts. Consistent with other research, students had difficulty generating and distinguishing sufficient evidence in the computer model to support their argument. Students can learn content while constructing an argument. However, they require guidance in argument practices particularly how to gather first-hand evidence and to integrate their ideas. In future studies we plan to strengthen the guidance features in the notebook, to better support students' integration and refinement of ideas as they develop their argument.

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