UTILIZING MATHEMATICS TO EXAMINE SEA LEVEL RISE AS AN ENVIRONMENTAL AND A SOCIAL ISSUE

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The phenomenon of the sea level rise is a pressing environmental and social issue of the present age. Starting with the assumption that mathematics can be utilized to help students explore this phenomenon, we designed a simulation in NetLogo, in which students investigated the relationships between the quantities of temperature rise, height of future sea level, and total land area. In this paper, we present the analysis of a whole-class design experiment in a sixth-grade classroom and discuss how our design helped students to examine sea level rise as both an environmental and a social issue.

Keywords: Social Justice, Interdisciplinary Studies, Technology, Mathematics for Sustainability

In 2001, The Intergovernmental Panel on Climate Change (IPCC) projected that the global sea level would rise up to .88 meters by 2100, which was only .09 meters in 1900 (Raleigh, Jordan, & Salehyan, 2008). Sea level rise would not only cause inundation and displacement of wetlands and lowlands, coastal erosion, and flooding (Nicholls & Mimura, 1998), it would also bear a severe impact on people residing in low-lying coastal areas (Rowley, Kostelnick, Braaten, Li, & Meisel, 2007) as these would be the first people to experience flooding. Further, damage of properties, loss of lives, and injuries caused due to increased sea level would disproportionately impact the poorer section of the society, who, despite being the least contributor to sea level rise, would be most vulnerable to its impact (Dodman & Satterthwaite, 2008). Lack of preparedness and financial limitation would make poor people more susceptible to the effects of sea level rise (Walker & Burningham, 2011). Hence, like any other climatic issue, sea level rise also qualifies as an issue of social injustice.

Climate Issues and School Curriculum

Research shows that the introduction of climatic issues in the school curriculum would help students as the future citizens to develop an awareness about and cultivate sensitivity towards the climate (Shepardson, Niyogi, Choi, & Charusombat, 2009). Mathematics education inarguably plays a significant role in the process. Mathematics literacy is not only necessary to identify the different traits that indicate climatic disruptions, but it also helps students to predict the future impacts of climate change (Barwell, 2013). Although school mathematics has traditionally modified itself and accommodated issues that marked the needs of the time, climatic phenomena have seldom been incorporated in mathematics textbooks or tasks (Renert, 2011). When Abtahi et. al. (2017) investigated Norwegian and Canadian mathematics teachers' opinion regarding inclusion of climatic issues in mathematics classroom, they found that even though the teachers acknowledge their moral obligation towards educating students about climate, they indicate that the complexity of climatic issues, the lack of students' mathematical and technical knowledge, and the lack of resources and time are some of the roadblocks towards implementation of climatic issues in mathematics classrooms. The study reported in this paper aimed to address those challenges by designing an interactive simulation and accompanying tasks and questioning that would help students explore the causes and consequences of sea level rise in a way that would make this complex phenomenon accessible to sixth grade students. Specifically, we report on how we assisted students to reason

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covariationally about the quantities involved and how this reasoning helped students understand how their own city can be affected by the sea level rise.

Design and Methods

Most of the information about sea level rise in the news and public media is in the form of data and graphs. To support students' interpretation of data and graphs, this study focused on students' covariational reasoning about the quantities underlying the phenomenon. Covariational reasoning involves coordinating two quantities as the values of those quantities change (Confrey & Smith, 1994). A student reasons covariationally when she envisions two quantities varying simultaneously (Thompson & Carlson, 2017). For instance, as air temperature increases, the height of sea level also increases. To support students' understanding of the sea level rise, we designed an interactive simulation and a set of integrated activities that asked students to reason about the relationships of the quantities.

We designed the Sea Level Rise simulation using NetLogo (Wilensky, 1999), a multi-agent programmable modeling environment. We hoped that the dynamic environment of NetLogo, together with its animated outputs and result plots, would provide students with a self-exploratory space to change and reverse change the values of different quantities, which is not always practical with physical manipulations. Four cities familiar to the students were selected and arranged vertically according to their elevations from the sea level (Figure 1). The user can drag the temperature rise slider to the left and right, manipulate its value, and observe the impact of the change on the height of sea level and total land area. The simulation was accompanied by a set of activities and discussion questions that we hoped would prompt students to reason about different covarying quantities and identify the environmental and social aspects of sea level rise. For example, questions such as "What would happen to Manhattan if height of future sea level doubles?" not only required students to focus on the covariational relationship between height of future sea level and elevation of Manhattan, but also to identify the consequences of sea level rise on lives of people living at lower elevation, such as Manhattan.

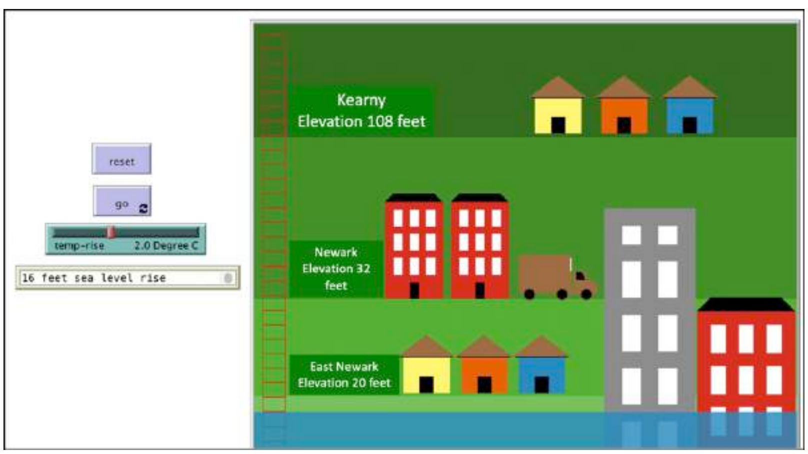

Figure 1: Sea level rise simulation

Our goal was to explore the ways that our design, which included engineering learning opportunities for students to reason covariationally, helped students to reason about sea level rise as an environmental and a social issue. More specifically, we examined the research question: *How did our design help students develop an understanding of sea level rise as an environmental and a social issue?*

This study took place in a public elementary school located in the North-Eastern part of the United States. We conducted a week-long design experiment (Cobb et. al., 2003) in a sixth-grade classroom containing 17 students. The teacher conducted the whole-class instruction and a research team member interacted with a small group of students. All the sessions were video recorded, transcribed, and coded using the software program Quirkos. In this paper, we focus on our interaction with a student named Ani to illustrate how our design helped students explore the phenomenon as an environmental and a social issue.

Findings

The Sea Level Rise simulation provided the students with a dynamic environment to drag the temperature rise slider and observe its impact on the height of sea level (Figure 2). For instance, when Ani was asked "What happens if I lower the temperature?," he dragged the temperature rise slider to the left and said, "the lower the height of sea level."

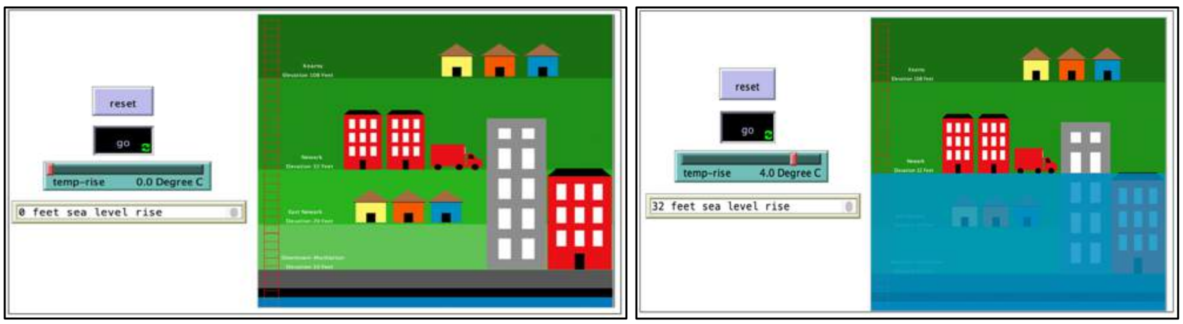

Figure 2: Temperature rise increases, height of sea level increases, total land area decreases

To prompt the students to reason numerically between the two covarying quantities, we asked them to graph the relationship between temperature rise and the height of future sea level. Students used the simulation to find the height of future sea level for different values of temperature rise and plotted the ordered pairs on a graph. When Ani was asked to explain the graph, he stated that the graph was "rising like super straight line" because "when temperature rises 0.5, it rises by 4 feet every time." From his response it seems that Ani attributed the "straight" shape of the graph to the constant increase of height of future sea level for a uniform change of temperature rise.

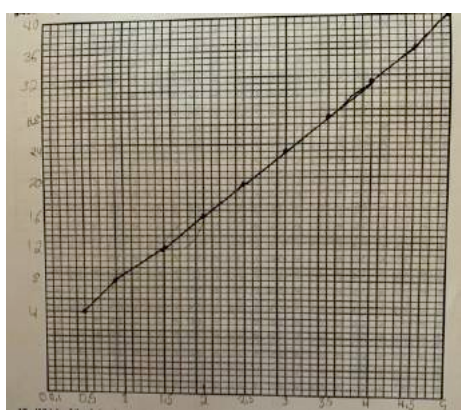

Figure 3: Ani's graph showing the relationship between global temperature (horizontal axis?) and height of future sea level (vertical axis)

To help students identify the consequences of sea level rise in their own lives, we encouraged them to think about the impact of sea level rise on total land area. When we asked Ani to state what would happen to the total land area if the sea level rises, he responded, “the less land, the total land area is going to be less.” He further justified, “because the more higher the sea level is, it takes over land. So, instead of land over water, it will be under water.” Through his reasoning, Ani identified the direction of change between the height of sea level and total land area. The graphics of the simulation (Figure 2) were powerful in helping Ani coordinate the direction of change of the two quantities. We further prompted Ani to think and explain why an increasing temperature results in a rise of sea level and a reduction of land area. Ani thought briefly and said, “The higher the global temperature, the higher the sea level. Rising the global temperature, the ice caps in the Antarctica will melt which makes more water to go into the water and sea level rises, which means less land area.” Ani not only explicitly described the relationship between the three quantities but also identified melting ice caps in Antarctica as a consequence of increased temperature and a cause of the rising sea level.

In the Sea Level Rise simulation, the inclusion of the names of places familiar to the students helped them identify the consequences of sea level rise in connection to their own lives. Students were relieved to find themselves located at a higher sea level, compared to their neighboring towns of Newark and Manhattan. They identified that if sea level rises, then that will “cause places like…low elevation like Newark go under water.” Students also expressed their anxiety about the lack of economic affluence of people to endure the impact of displacement caused by flooding. For example, during the small group conversation when we asked the students, “What is going to happen to our home (if sea level rises)?”, Ani replied, “It is gonna be destroyed, and we cannot rebuild it.” Further, he added that the situation would be different for rich people, since their homes would also be “Destroyed, but they can rebuild it.” Ani resonated the argument of Dodman and Satterthwaite (2008) that climatic threats, such as sea level rise and flooding are issues of social injustice since they bear down a disproportionate impact on the people belonging to different socio-economic strata. The students’ articulations “they can rebuild it” and “we cannot rebuild it” indicate that students recognized how low socioeconomic conditions of certain people limit their access to resources and opportunities to fight the impact of climatic disruption.

Conclusion

Consistent with Barwell’s (2013) assertion, this study illustrates that students’ mathematical reasoning provided them a platform to engage in a meaningful discussion around sea level rise. Students not only reasoned covariationally between rising air temperature, height of future sea level, and total land area, and examined the environmental aspect of sea level rise, they also explored the social aspect of the climatic phenomena. Students identified that economic disparity makes poor people more vulnerable to the risk associated with sea level rise (Dodman & Satterthwaite, 2008), while wealthy people possess both resources and financial stability to escape its impact. So, through this study we convey that incorporating climatic issues in mathematics classroom is complex, but it is high time that mathematics educators and researchers acknowledge their roles and responsibilities in empowering students mathematically and helping future citizens to become more sensitive towards the climate.

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