Teaching Secondary Mathematics Students about Climate Change: Towards an Environmentally Conscious Mathematics Education in Hong Kong

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Introduction

According to Barwell (2013), climate change is one of the most pressing issues of the 21st Century. Indeed, we live in increasingly complex and uncertain time with almost irreparable destruction to our ecosystem, with the climate crisis being a prime example of human's impact on the ecosystem. Addressing the "global emergency" in 2019, the United Nations (UN) warns that only eleven years was all that remain to stop irreversible damage from climate change (UN, 2019). On the other hand, Barwell (2013) stated that, "mathematics is involved at every level of understanding climate change, including the description, prediction and communication of climate change" (p. 1). Despite this powerful statement, most of us go about our usual business of teaching mathematics and problem solving as if the climate crisis never existed. Yet ironically, we routinely teach mathematics as if solving "how old is Mary" or "when will two trains meet[38]" are meaningful problems with real-life significance. In reflecting about our current mathematics curricula and instruction, we ask, "Does mathematics education have a role in educating school children about pressing environment issues?"

In response, we are drawn to the work of Renert (2011), who calls for issues of sustainability—for living systems to coexist over time—to be included

38 See Gerofsky's (2004) book on word problems as genre in mathematics education.

in the mathematics curricula. In his essay published in *For the Learning of Mathematics*, Renert (2011) pointed out that, by and large, ecology has played only a negligible role in mathematics education. Further, he explained that mathematical reasoning and numbers can bring important perspectives about the environment and responses to issues of sustainability. In a transforming response, "the process of sustainable development is essentially one of learning, while the context of learning is essentially that of sustainability […] Stakeholders make connections between multiple layers of purpose that include: physical, economic, environmental, emotional, social, and spiritual" (p. 22). Likewise, we suggest that a sustainable mathematics education is much more than learning about numbers, but noticing the world differently through numbers, and to make responsible decisions with the goal of improving the wellbeing of not only human civilizations, but also their environment and the eco-system at large.

In this paper, we argue that educators can do much more to conceptualize and transform mathematics teaching and learning to fit with the time and place we find ourselves, in which environmental consciousness is a priority in all sectors of society. In what follows, we illustrate how mathematics education can play a role in educating students about the climate change and environmental sustainability. Especially, we envision that mathematics classrooms can be a venue for students to work with climate change in three ways (Abtahi et al., 2017): *to learn mathematics*, *to learn about climate change* and *to encourage critical thinking*. In each of the three sections below, we discuss our design of lessons and projects that can be implemented in Hong Kong's secondary mathematics classrooms in contributing towards an environmentally conscious mathematics education.

To teach mathematics in the context of climate change

Environmental issues are more urgent than some global citizens could imagine. The era of Anthropocene suggests that we currently live in a time and place with significant and destructive human impact on Earth's geology and ecosystems. Therefore, resolving the issue, or at least easing the situation,

requires communal effort from many parties and sectors of society. Effective communication is thus a vital component in strategizing a resolution, and mathematics is one of the major tools when it comes to, for example, communicating the effect and magnitude of climate change. As such, helping students to acquire mathematical literacy in the areas of data handling and statistics is an important step for students to notice and make sense of these pressing environmental issues.

Statistics is the study of collecting, analyzing, interpreting, explaining, and presenting data. In particular, statistical graphs are commonly used to present data in our daily life. For example, we see the use of statistical graphs in commerce, trades, medicines, weather forecast, etc. on a daily basis. On the other hand, when reflecting on the kinds of statistical graphs used in mathematics textbooks, we realize that many of them represent irrelevant and unreal data, such as "Favorite Colours of Class 1B" or "Hourly Fees for Personal Trainers". We believe that these examples constitute a missed opportunity for our students to learn and make connections with the world around them. Instead of asking students to analyze irrelevant and unreal data, or to produce statistical graphs from these data, we could utilize authentic data and statistics, such as those about climate change, to teach data handling and statistical concepts in mathematics classrooms. Students could thus analyze something real and relevant to their lives, which not only serves as a source of new knowledge about the environment, but also boosts their motivation in learning mathematics.

For instance, we suggest that mathematics educators can engage students with concepts like normal distribution, standard deviation and confidence interval with the following graphical images[39] (Skoll et al., 2017). The series of graphs in Figure 1 show the global summer temperature change since the mid-1900s, beginning from 1951 through 1980 (Figure 1a), where the white

39 We encourage the readers to engage with the documentary, "The Inconvenient Sequel: Truth to Power" (Skoll et al., 2017) from which these images were drawn from [See: 07:23 to 08:16 timeframe of the documentary]

portion are the normal days, the blue (marked "B") are the cooler-than-average days, and the red (marked "R") are warmer-than-average days. Starting in the 1980s, the entire curve shifted to the warm side, and for the first time, a statistically significant number of extremely hot days is observed in the period of 1983 to 1993 (Figure 1b). The curve shifted further in the 1990s (Figure 1c). To date, the extremely hot days have become more numerous than the cooler-than-average days (Figure 1d). In a statistics lesson, we can utilize graphs like these to show, compare, and analyze global or local[40] summer temperature change over time, from which we can discuss with our students the evidence, magnitude, and significance of climate change.

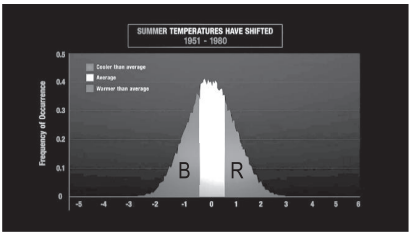

Figure 1(a)

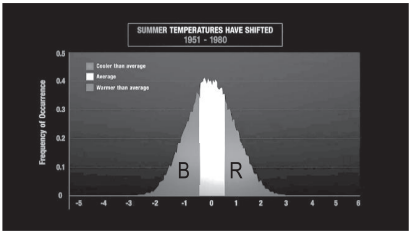

Figure 1(b)

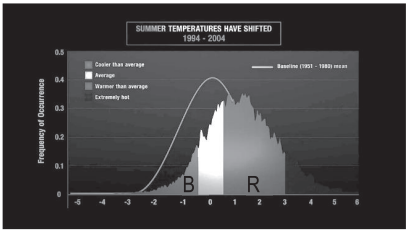

Figure 1(c)

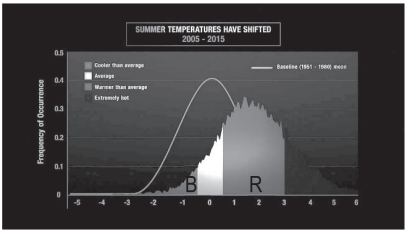

Figure 1(d)

Figure 1(a)-(d). Global temperature change from 1951 to 2015 [Source: Skoll et al., 2017].

In the Junior Forms of Secondary classes, we can also teach data handling topics in the context of climate change, as follows. We can provide different

40 We suggest locating Hong Kong climate change data and statistics in Hong Kong Observatory's website: https://www.hko.gov.hk/en/climate_change/climate_change.htm

types of graphs with real climate change data and have students discuss the advantage of presenting data with specific types of graphs, and even discover common misuses of graphs or abuse of data. Thus, we aim at teaching students statistical knowledge while also guiding them to learn more about environmental issues. Given that these are real data, students could also learn to critique the evidence given by different parties, thus gaining a more comprehensive understanding on the issue. Such ways of teaching mathematics are also likely to spark students' interests in learning mathematics as beyond obtaining the "correct answer" (Renert, 2011).

To teach environmental sustainability through mathematics

Where statistical graphs provide a big and general picture of environmental issues, the data represented are usually too macroscopic to make sense for students personally. Besides using real but large-scale data where countries or places are the base units, data collected by students themselves could have a more immediate and personal impact on students, thereby guiding them towards awareness of environmental sustainability. For example, when we talk about annual water consumption in Hong Kong[41], we describe it in terms of millions of cubic meters, which makes no sense for students how much water is really consumed. Even when reading water bills, it reports water usage per household per month, which does not always help students realize how much water they use. Therefore, we propose that an investigation-based task can be conducted, in which students would actively find out some interesting facts about themselves, such as their own water usage for a certain daily routine. The advantage of these kinds of tasks is that students are actively collecting their own data instead of being given the data. For example, we can invite students to investigate and then compare water usage between taking a bath and a shower every day. In terms of mathematical content, students may use rates and proportion to

41 According to the Water Supplies Department (WSD), Hong Kong consumes more water (fresh and salt water) per capita when compared to most other first world cities. On average, Hong Kong's daily domestic fresh water consumption per capita is 130 L; around 40% of that is used for showering/bathing. [Source: https://www.waterconservation.gov.hk/en/why-save-water/virtual-water/index.html]

calculate the volume of water they need to take a shower, while they will apply their knowledge of volume of prisms in the bathing case. In both situations, students will also draw on their estimation skills and apply different strategies to optimize their estimations. In doing so, students would realize how much water they are actually using, and how much they could have saved if they had taken a shorter shower, or had taken a shower instead of a bath. Furthermore, we think that the following questions can be asked of students from Junior Secondary Forms to engage them with environmental sustainability:

1. Record the time you spent for a shower this week. Use this to estimate the total amount of water you used for this week, and find the mean and median water usage. What do the mean and median tell you about your water usage?

2. Estimate the amount of water spent if you turn on the tap for one minute. Find the percentage decrease of amount of water used if you had used the showerhead instead.

Overall, this investigation-based project helps students to know more about water usage and encourage them to present their individual findings obtained from their homes and discuss them with their peers. At the same time, different mathematical concepts are called upon in the questions, such as descriptive statistics and percentage change respectively in the above questions. Finally, students would become aware of their responsibilities in preserving the environment with mathematics as tools for investigations. We could even consider introducing research projects on related topics, such as the "water footprint[42]" for various food production (Figure 2), thus guiding students to reflect more deeply upon other relevant environmental issues through the lens of mathematics. We believe that students would get the message that they can be

42 Water footprint is the amount of water used to produce each of the goods and services we use. According to UNESCO WWAP (2015), agricultural water consumption accounts for 70% of the total freshwater consumption.

active agents for resolving environmental issues, and that mathematics could be useful for understanding something relevant to them.

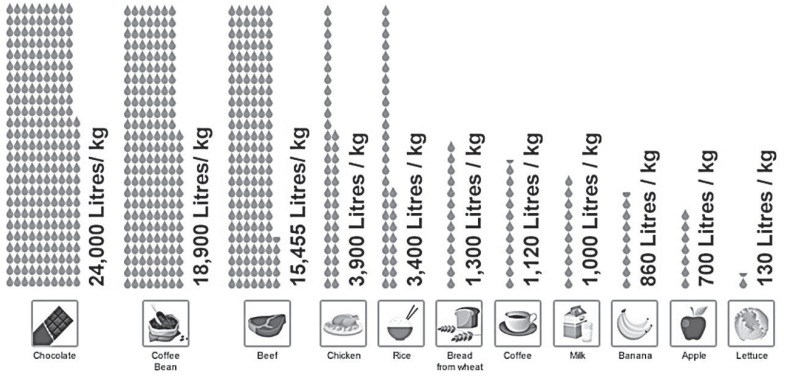

Figure 2. Fresh water used to produce one kilogram of food or 1L of drinks [Source: Water Footprint Network]

To encourage critical thinking

Apart from helping students learn mathematics and raising their awareness of environmental sustainability, we envision mathematics education as a place to train our students to be critical and relational thinkers. Mathematics, more than a computational tool or some abstract knowledge, can be considered a tool for critical thinking, since numbers could show facts and present the ideas objectively. For example, through introducing a task of calculating carbon footprint, we could lead our students to understand that almost every act in our lives could cause damage to our planet. Guiding students to think about the balance between protecting the environment and developing human civilization will be a great way to encounter critical thinking.

At first, students may use online resources to learn about the concept of carbon footprint[43]. Then, they can also use the various formulae to calculate the carbon emissions they generated from their different facets of life (e.g. “household”: electricity, gas, waste, water; “travel”: bus, MTR, rail, ferry,

43 See, e.g., https://www.climateready.gov.hk/ and https://www.carboncalculator.gov.hk/en

airplane; “food”: meat, dairy, oils, snack; “consumables”: electronics, clothes, recreational). Upon comparing their own annual carbon footprint with that of an average person in Hong Kong[44] (Figure 3) as well as in other countries, students could set up a carbon reduction plan and calculate how much carbon footprint may be reduced in the plan. It could be as minor as spending less time in the shower, or some bigger decisions such as reducing air travels. We can truly see the effect of our actions on preserving the planet through this activity, thus building a sense of belonging as a global citizen.

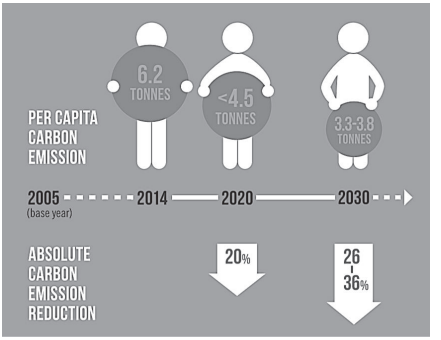

Figure 3. Summary of Hong Kong’s carbon emission targets (per capita)
[Source: Environment Bureau, 2017]

Next, when students well understand that different facets of their daily life could increase their carbon footprint, we could ask students to discuss the following questions:

1. Why should we reduce carbon footprint?

2. What would happen if we reduce carbon footprint to zero?

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44 In 2018, the average Hong Kong person released about 5.9 tonnes of carbon into the atmosphere (not including carbon emissions from air travel). This is far from the target of 3.3-3.8 tonnes by 2030 as stated in the “Hong Kong Climate Action Plan 2030+”. [Source: https://www.scmp.com/news/hong-kong/health-environment/article/3046358/watch-your-carbon-footprint-hong-kongs-getting]

3. Is there any relation between the amount of carbon footprint and economics?

In particular, the third question is key for students to think about the balance between protecting the environment on one hand, and developing human civilization on the other. Equilibrium is an all-important concept when we talk about relations between the environment and economics. Through asking students to prepare data for a discussion or even debate, critical thinking could be encouraged as they must stand with their points with solid evidence and rational facts. Moreover, this activity is more than just using strategies; it involves making strategic decisions about oneself. Hence, relational thinking is fostered with a disposition of having a habit of thinking before acting.

Conclusion and looking forward

Hong Kong saw its warmest year on record in 2019, which was also the second-hottest year ever recorded on the global front. As mathematics educators, we know well and preach that solving a problem requires us to first understand the problem situation (Pólya, 1945). Yet, in relation to climate change and environmental sustainability, there are still many people who are not aware of the severity of the current crisis. Therefore, we believe that our roles as mathematics educators are twofold: to continually contribute towards mitigating climate change by our own actions and act as a role model for our students and peers, and at the same time, to spread the message so that others could also understand the severity of the "problem". No doubt, as we have discussed in this paper, mathematics can serve as a tool to help us interpret, communicate, and analyze the emergent and complex issues that relate to the global village at large, and local environments in particular. Our efforts to teach mathematics in the context of climate change, to teach environmental sustainability through mathematics, and to encourage critical thinking in the mathematics classroom shall prove productive in educating the next generations of Hong Kong citizens to be informed and responsible individuals in relation to the climate crisis. As much "footprints" of carbon we have left on this earth, we are optimistic and hopeful that our students will "step" onto the journey for global climate

movement through our visions and approach towards an environmentally conscious mathematics education.

Acknowledgment

This paper is supported by the World University Network Research Development Fund (WUN RDF project title: Innovating the mathematics curriculum in times of change: Towards local and global relevance). The authors are extremely grateful for all student teachers who are enrolled in BMED 4510 (19-20) for their fruitful discussions and reflections over the thesis of this paper.

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