Raising Students' Awareness and Actions Through a Sustainability Project

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Little research is evident about integration of mathematics in sustainability tasks to raise students' awareness and actions to solve a sustainability challenge. In this paper, we explore how a teacher designed and implemented a sustainability project, which included mathematics to raise Year 10 students' (aged 15–16) awareness and actions about sustainability. Data, including classroom observations and interviews, were analysed based on one characteristic of the green mathematics framework: *projection*. We report on how students used mathematics to project future situations and how the projection may raise students' awareness and actions to address sustainability.

Greta Thunberg has been school-striking every Friday for years to campaign for climate justice; her campaign has inspired other people including students from all over the world to do the same (Sabherwal et al., 2021). To participate in public discussion and debate to convince people about the urgency of climate change, students need to understand how climate change eventuates and how to address the problem (Barwell & Hauge, 2021). School education can play a pivotal role in engaging students in the topic of sustainability and providing opportunities to become curious about and aware of current environmental challenges (UNESCO, 2020).

"To develop students' ability to tackle real-world problems and apply mathematical knowledge successfully, schools and education systems need to go beyond formal mathematics education" (OECD, 2023, p. 60). Formal mathematics education aims to help students understand mathematics concepts and use them to solve problems that relate to reality. However, such problems are often intentionally simplified for educational purposes (Vos, 2018). Meanwhile, problems that humanity faces, such as climate change, are very complex (Barwell & Hauge, 2021). If students are only taught mathematics as a means to solve contrived problems, it may be challenging for them to use mathematics in complex real-world problems (Tran & Dougherty, 2014). Therefore, students should be given the opportunity to investigate complex problems, including sustainability challenges, using mathematical ideas.

Sustainability has been increasingly included in school curricula and research has shown how teachers have taught sustainability either through learning areas (da Silva-Branco & Woods-McConney, 2021) or co-curricular projects (Anggraena et al., 2022). However, little research is evident about how their implementation used mathematics to raise students' awareness and actions. In this paper, we aim to explore how a high school teacher, Kartini (pseudonym), designed and implemented a sustainability project, in which students investigated a local environmental challenge, then proposed and took actions in addressing the problem. We used the green mathematics framework (Salim, 2023) to analyse the project design and implementation to understand how projects could raise students' awareness and actions.

Educational Policies and Sustainability: Raising Knowledge

The United Nations Educational, Scientific and Cultural Organization (UNESCO) has called on all countries to start teaching students about climate change and other sustainability challenges through Education for Sustainable Development (ESD) for 2030 (UNESCO, 2020).

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ESD for 2030 aims to "raise knowledge, awareness, and action" (p. 17). Some countries have already included sustainability into their curricula (e.g., Anggraena et al., 2022; da Silva-Branco & Woods-McConney, 2021). In Australian curriculum, for example, sustainability is one of cross-curriculum priorities, which is to be integrated across learning areas. In Indonesia's new curriculum (known as *kurikulum merdeka* or *emancipated curriculum*), sustainability is one of seven co-curricular project themes, taught separately from intra-curricular subjects (learning areas in Australian curriculum) (Anggraena et al., 2022). Indonesian schools must allocate 25–30% of school time to thematic co-curricular projects.

Such educational policies aim to give opportunities for students to learn about sustainability challenges, but only teachers can provide students with a learning experience that is meaningful and potentially raises their awareness of sustainability challenges (UNESCO, 2020). Some Australian teachers self-reported that they were able to integrate sustainability across learning areas like science, digital technologies, and mathematics (da Silva-Branco & Woods-McConney, 2021). Likewise, some Indonesian schools have implemented a sustainability themed co-curricular project (Anggraena et al., 2022). However, little research is evident about how the integration of sustainability into learning areas (especially mathematics) can influence students' awareness and actions. In the next section, we discuss how mathematics and sustainability education can be integrated to raise students' awareness.

Integrating Mathematics and Sustainability Education: Raising Awareness

The focus in mathematics classrooms is often on concepts and procedures, which can be categorised as formal mathematics (OECD, 2023; Schmidt et al., 2022). Word problems, intended to show how mathematics can be used, are often inauthentic and lack complexity of realistic situations. Students may therefore focus only on prescribed mathematical procedures, disregarding the problem context (Lubienski, 2000; Palm, 2007). However, mathematics education could play a role in supporting students' understanding and awareness of complex sustainability challenges (Barwell & Hauge, 2021). For example, by investigating variability in data collection, students could experience some of the complexity of a real-life system (Dierdorp et al., 2017). Using mathematics as a tool to analyse the system and interpret data within the system provides a path to building awareness of a sustainability phenomenon.

Another important aspect to consider is that students need to have purpose to use mathematical ideas (e.g., measurement and statistics) if they are to meaningfully analyse data to understand a problem (Ainley et al., 2006). Sustainability contexts that can be related to students' lives may motivate them to use *authentic* data to investigate a *complex* problem thoroughly (Smith & Watson, 2023). The more the students consider the task as being authentic and understand the complexity of a sustainability challenge, the more likely they become aware of the problem that addressing this challenge presents (Endsley, 2017). In addition to importance of authenticity and complexity, Salim (2023) previously emphasised that integrating mathematics and sustainability education requires opportunities for *projection* (Figure 1). After outlining the green mathematics framework, we explore how opportunities for projection may strengthen sustainability projects by invoking students' actions to address a sustainability challenge.

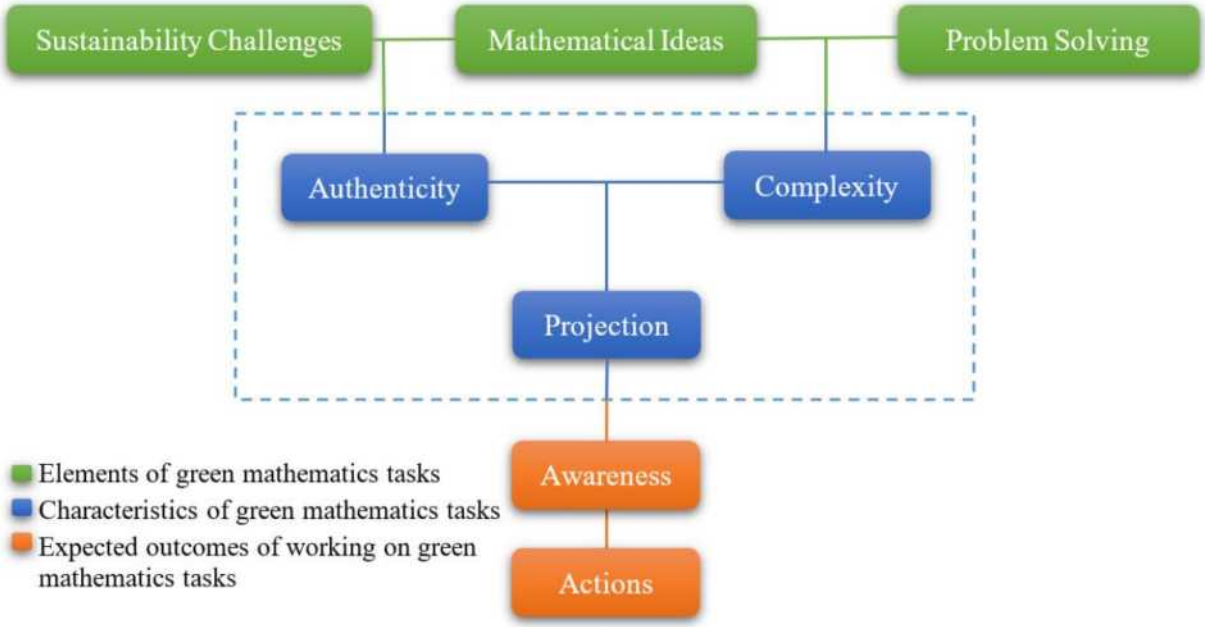
Projection in the Green Mathematics Framework: Raising Actions

Three basic elements need to be present in tasks or projects that allow to successfully integrate mathematics and sustainability education: a sustainability challenge(s), mathematical ideas, and problem solving. These elements are interdependent; missing one of them may make it difficult for students to understand a sustainability challenge (Salim, 2023). We explained above that to raise students' awareness, the task also needs to be *authentic* and *complex*. By *authenticity*, we refer to adoption for classroom use of data/information, context and problem

related to a sustainability challenge that has happened, is currently happening, or is predicted to happen, and where task designers expect that students would come to have a stake in addressing the challenge. *Complexity* refers to the extent to which the task is presented in a classroom as a real-life system, where mathematical ideas and activities (e.g., data collection and analysis) may need to be called upon when students engage in the task. To raise students' actions to address a sustainability challenge, the students need to encounter a need to project (predict or estimate) future possibilities of the sustainability challenge being investigated in the task (Endsley, 2017).

Figure 1

The Green Mathematics Framework (Adapted from Salim, 2023)



The term *projection* in this framework refers to predicting and visualising future implications based on current data and information (which is different from projection in geometry). Making predictions requires students to reason and make sense of patterns and "allows students to activate and refine their existing knowledge [and] … to increase students' level of engagement" (Lim et al., 2010, p. 598). Likewise, projection in the green mathematics framework is expected to support students in attending to patterns and connections between past, present, and future situations (Endsley, 2017), thus engage in activities that are overtly mathematical while working towards understanding a sustainability problem.

The complexity in the framework is expected to give students opportunities to investigate a sustainability challenge as if they were experts and scientists in the field who engage in a real-world problem solving activity (Schoenfeld, 2016). Projecting throughout a complex sustainability challenge may allow students to see a problem from different perspectives. The projection makes it possible for students to see themselves being impacted by or perhaps contributing to the problem, which can raise not only their awareness of the problem but also a need for action. By allowing students to see themselves in future situations, projection may motivate them to explore possible solutions and actions to avoid unwanted outcomes.

Research Methods

This paper is part of a research project exploring a case in which a high school teacher, Kartini, designed and implemented a sustainability project, following Indonesia's *emancipated curriculum*. We employed the green mathematics framework to analyse the design and

implementation of Kartini's sustainability project. In this paper, we focus on how students used mathematics in making *projections* and how this raised their sustainability awareness and actions. The project was designed by a team of teachers, but only Kartini (the chair) participated in this study. The data were collected through interviews with Kartini, classroom observations, focus group discussion with students, a survey for students, and document artefacts.

School Context, Participants, and the Sustainability Project

The research was conducted in an Indonesian Islamic secondary boarding school. The school was established in a village surrounded by green mountains, located around 35 kilometres from the nearest city centre. The school employed approximately 50 teachers and accommodated around 150–200 students from Year 10 to 12 (15–18 years old). The school started implementing the *emancipated curriculum* in 2022. Kartini is a biology teacher with four years of teaching experience. She designed the sustainability project for Year 10 students (15–16 years old). Twenty-seven students who worked on the project participated in this study.

Kartini and the team designed the sustainability project to address a local environmental challenge in the school: *waste management*. Kartini was concerned about the waste being burnt around the school and not managed properly. Since the students spent most of their time at the school, they were familiar with the issue. Through this project, Kartini involved the students to investigate the problem in order to make them aware that they were contributing to the school waste. This project was implemented in five sessions (3–4 hours each). First, Kartini explained the project's aims and introduced the waste problem around the school (*introduction*). The students then collected data about the school waste in groups (*contextualisation*). Each group investigated different types of waste (e.g., single-use plastic bottles, food waste, and paper). In the next session, each group presented their data and findings to other students in a *mini exhibition*, then they reflected on their findings to discuss possible actions to address the waste problem. The students carried out proposed *actions and solutions*, and, in the last session, they *reflected* on the project.

Data Collection and Analysis

In this case study, four audio-recorded interviews (30–60 minutes) were conducted with Kartini: one interview before the project implementation and three interviews afterwards. Of five project sessions observed, only two could be video recorded due to the nature of the project that was mostly outdoors and required the students to interact with non-participants. After the project implementation, the students participated in a focus group discussion and filled in a short, anonymous survey to explore their experience in working on the project. Copies of documents related to the project (e.g., students' work, the project's plan) were also collected.

The data were analysed by identifying *critical* events, defined as episodes in which students use mathematics as part of their project work, and then coding the transcriptions based on the green mathematics framework (Powell et al., 2003). More specifically, we focused on analysing a set of questions requiring students to make predictions and estimations, which we term *projective questions*. The data were analysed to investigate how the *projective questions* in the sustainability project oriented the students to use mathematics to understand the local waste problem (raising knowledge). We also investigated how the projection could raise students' awareness and actions to address the problem.

Results

We report on the analysis of the projective questions in the sustainability project, students' projections, and their responses to the waste problem after the project implementation.

Projective Questions in the Sustainability Project

Kartini and her team designed what they called the 'Save The Earth Project', in which five structured questions were created for students (Figure 2). Questions 1, 2, and 3 required students to observe and collect data around the school related to waste production and management. Questions 4 and 5 required them to predict the future situation based the data collected.

Figure 2

The Questions Designed by Kartini's Team as Part of the Sustainability Project Design

Save The Earth Project

Bahasa Indonesia	English
1. Menurut Anda, sampah/limbah apa yang diproduksi di lingkungan sekitar Anda?	1. In your opinion, what kind of waste is produced around your (school) environment?
2. Bagaimana pengolahan sampah/limbah yang diproduksi di lingkungan sekitar Anda?	2. How is the waste managed around your (school) environment?
3. Berapa banyak produksi limbah yang dihasilakan tiap hari? (Dapat diperoleh melalui wawancara atau survey ke warga sekolah)	3. How much waste is produced every day? (You can find the data by interviewing or surveying the school community)
4. Buatlah prediksi berapa jumlah sampah yang dihasilkan dalam jangka 5 tahun dan 10 tahun ke depan!	4. Estimate how much waste will be produced in the next 5 and 10 years.
5. Buatlah prediksi apa yang terjadi jika permasalahan tersebut tidak dapat diselesaikan dengan baik!	5. Predict what will happen if the problem cannot be solved properly.

These questions make the sustainability project complex because students had to plan how they collected the data (research design), how they analysed the data (proportion, percentage, and statistics), and how they presented their findings (graphs, charts, and tables) in a mini exhibition. The aim of these questions was indeed to investigate the waste management, including the waste sources, as well as its current and future impact.

> The aim I made the questions is so that students become aware of the fact that the waste they produce, although it is small and often neglected, but if it is accumulated in a month, two months, or even in one year, that can be a lot. My aim for the questions … is to make it well-structured, so that there is a visualisation regarding the source of the waste, either in small or big amount, it is from us. Hence, later when doing the actions, certainly any small things that can be done need to start from us first. (Kartini, Interview 1, 12:09)

Kartini did not ask students about waste production in the abstract, but she sought to help students to envision their personal contributions to the waste production problem. Her questions encouraged the use of mathematics to facilitate students' predictions, and hence projection towards personal awareness and future action.

Projection Throughout the Project Implementation

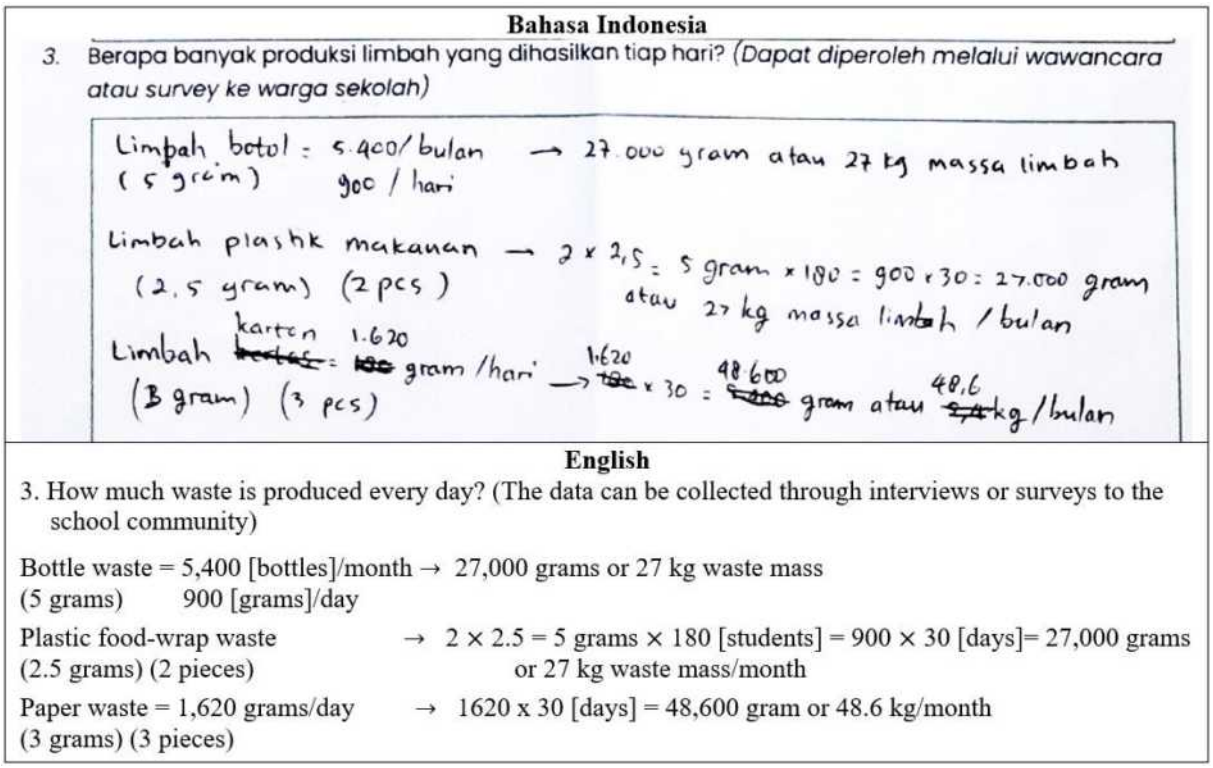
In the introduction session, Kartini asked her students to work in groups on the questions. Figure 3 shows an estimation made by Nadya's group in response to question 3. The students estimated that in one day each student used one single-use plastic bottle, two pieces of plastic wraps, and three pieces of paper. They estimated the mass of each and calculated that if there were 180 students in the school, how much waste they would produce in one day and one month. The quantities increased significantly when the students responded to question 4, projecting that in five years students at the school would use 1.6 tons of single-use plastic bottles and food wraps respectively, and 2.9 tons of paper. In ten years, these numbers were doubled.

Other groups made different estimations than Nadya's group estimations. Instead of using 180 students, one group used 130 students considering the Year 12 students had graduated (Introduction Observation, 01:23:39). Another group used 148 people by including the school

staff (Introduction Observation, 01:44:02). The evidence showed how students considered different variables that could influence their estimations.

Figure 3

A Group Students' Estimation of the School Waste Production



In the contextualisation session, each group collected data about different types of waste. This time, students used collected data (rather than estimates) to make a projection. Nadya's group collected data about students' use of single-use plastic bottles. In the focus group discussion, I asked the students which part of the project helped them to understand the waste problem. The following was Nadya's response, "when collecting the data, we finally know that the students at the school produce, um since I am in the plastic bottle group, so I know that on average a student uses one to two bottles per day" (Focus Group Discussion, 09:47).

The students found that, on average, each student used one to two plastic bottles per day. This was higher than their estimation in the introduction session (one bottle per student per day). This means that their initial estimation in Figure 3 could be doubled. Most students agreed with Nadya that the data they found from interviewing the school community (students, teachers, and staff) helped them to understand the problem better.

Students' Awareness and Actions

While implementing the project, Kartini noticed some changes in the students' behaviours:

> After the mini exhibition, I saw that the students have been cautious to sort out their plastic waste. In their dormitory, I got information that in every level—there are three levels there—students have provided bins for plastic waste. (Interview 2, 03:54)

Only a couple of students seemed to believe that "the waste problem in the school is not very urgent" (Survey #1). Most students' survey responses show that the sustainability project made them aware of the waste problem and that they needed to solve the problem immediately. For example, one student wrote "I became aware that waste is a serious problem that if not addressed, will lead to a huge problem" (Survey #15). Another student responded, "the sustainability issue needs to be addressed properly to prevent negative impacts from the

problem" (Survey #14). Based on these responses, using current data to project the future situation of the waste problem may have helped the students to become aware of how serious the problem was. They then proposed some solutions like sorting out recyclable materials, encouraging the use of re-usable tumblers, and urging the school to provide water dispensers. Ultimately, they used the data not only to justify their proposed solutions, but also to raise other students' awareness and actions during the mini exhibition.

Discussion and Conclusion

The analysis showed that as the students used mathematics to project future situations, they became more aware of the environmental challenge and proposed actions to address the problem. The results indicate that the projective questions in the design and implementation of the sustainability project had likely helped the students to become aware of a local sustainability challenge and motivated their actions to tackle the problem. In this part, we discuss two notions that could have contributed to raising students' awareness and actions: *purpose* and *projection*. First, because the context in the project was made local and relevant to their lives, the students had their own *purpose* to use mathematics when attempting to understand a real-world situation (Ainley et al., 2006). The students might have learned the mathematics (e.g., proportion, percentage, and statistics) previously and used it in a pseudo-realistic problem. An authentic, relevant context allowed the students to notice utility of mathematics in understanding a local sustainability challenge. Having used mathematics as an essential tool in analysing and interpreting environmental data, the students encountered mathematics as being important to addressing an environmental problem (Barwell & Hauge, 2021).

In Kartini's view, quantifying the school's waste production was essential to making students aware that the accumulation of individual production of waste could make a significant impact. This is where *projection* of the future situation based on the data that they collected could have helped students to clearly see their own impact. For example, the students predicted that in the next five years, their school will have produced around 1.6–3.2 tons of single-use plastic bottles if 180 students keep using 1–2 bottles each every day. This could be a great opportunity to further engage the students to think about sources of variability in their projection (e.g., whose waste production was included) to make the practical use of mathematics even more authentic and realistic (Dierdorp et al., 2017).

Questions 4 and 5 in Figure 2, which we refer to as projective questions, made it possible for students to envisage the future situation of the waste problem. The student projections were based on two variables: the number of students and the amount of waste produced by each student per day. As the number of students was not likely to decrease in the future, the students explored actions and solutions that could reduce the individual waste production, such as water dispenser and re-usable tumbler use in school. The findings from the projections were used to justify the proposed solutions and then to convince the school and other students (the mini exhibition visitors) to take actions.

To conclude, purposeful use of mathematics appears to be essential in integrating mathematics and sustainability education. Including the need for *projection* (e.g., from current to future data) in a task or a project design appears to afford mathematics use to become purposeful from students' perspectives. Additionally, choosing a local problem that can readily be brought to matter to students may play a pivotal role in whether students choose to engage in complex project activities (e.g., data collection, exhibition, etc.). As the problem matters, the students have their own *purpose* to work on the project and motivate their actions to use mathematical ideas to understand and address a local sustainability challenge.

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