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Realizing the Urgency of Microplastic Issues Through Mathematics Realistic Education: A Hypothetical Learning Trajectory Based on ESD

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ABSTRACT

Despite the growing awareness of microplastic pollution, public understanding of its severity remains limited, partly due to the abstract nature of environmental issues when presented without quantitative context. Mathematics can help address this gap by offering measurable representations of environmental impact. However, the integration of mathematics and environmental education, faces significant challenges, including curriculum limitations and a lack of teacher training. To address these issues, this study proposes a Hypothetical Learning Trajectory (HLT) using the context of microplastic pollution as an entry point to support Education for Sustainable Development (ESD) through mathematics learning. Grounded in the principles of Realistic Mathematics Education (RME). The design includes five core learning activities and is guided by the ESD framework by Commonwealth and Indonesian national curriculum standards. This study contributes a structured approach for integrating sustainability issues into mathematics education, aiming to foster both critical awareness and mathematical thinking.

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Public awareness of microplastic pollution has grown in recent years, yet the perceived severity of the issue often remains vague or underestimated. Microplastics, defined as tiny plastic particles less than 5 millimeters in size, are pervasive pollutants that pose risks to both environmental and human health. Despite increasing media coverage and scientific reports highlighting their dangers, people often struggle to fully comprehend the extent of their impact. This is largely due to the abstract nature of environmental problems, which make conceptualization of the problems difficult, particularly when described without quantitative context. For instance, Aprilianti (2024) estimates that an individual may ingest an amount of microplastics equivalent in mass to a credit card each month. Similarly, ECOTON (Ecological Observation and Wetlands Conservation) reports during 2022 to 2024 indicates that people in Indonesia may inhale up to 90 microplastic particles per hour. Such statistical representations do not merely convey information, but they play a critical role in emphasizing the severity of the issue by providing measurable indicators of human exposure. By making the scale of environmental degradation more explicit, mathematics contributes to raising awareness and fostering a deeper understanding of its real-world implications. Eventhough, mathematics may not directly resolve environmental challenges, but it plays a critical role in enhancing students' conceptual understanding by offering a logical and evidence-based framework for interpreting real-world phenomena (Barwell, 2018).

However, despite the potential of mathematics in addressing environmental issues, there is limited integration of mathematics and environmental science in formal education contexts. Some researchers such as Li & Tsai (2022), Su et al. (2023), and Zulu & Sanjigadu (2024) have noted that in the existing research literature, the integration of mathematics and sustainable development including environmental issues is still at an early stage so the topic has only scratched the surface, especially in terms of learning content, pedagogy and learning environment. This is due to the practical challenges in the integration of mathematics and environmental education in Indonesia faces various challenges (Lestari et al., 2024), so the problem of the lack of integration between mathematics and environmental issues in formal education requires greater attention.

One of the challenges is that there is no explicit sustainability component in the school curriculum, making it a challenge for educators to integrate Education for Sustainable Development (ESD) into various subjects, including mathematics (Kanandjebo, 2024). In addition, the lack of professional development and training for teachers in designing contextual learning is also a significant barrier (Lestari et al., 2024). Many teachers have not received adequate guidance to develop innovative and context-based teaching methods. This makes many teachers feel less confident or unprepared to explore environmental topics in mathematics learning.

Given these challenges, Realistic Mathematics Education (RME) emerges as a promising pedagogical approach to bridge the gap between mathematics education and pressing environmental issues such as microplastic pollution. The Realistic Mathematics Education (RME) approach is one strategy that can bridge the need for contextual learning and re-construction of mathematical concepts through real problems faced by students so that learning is more meaningful and relevant (Hakim et al., 2024; Khairunisa et al., 2024). The term 'realistic' is frequently misunderstood or interpreted in a limited sense. In Dutch, 'realistic' is interpreted as *zich realiseren* which means *to be aware of or to realize* (Drijvers, 2022; Guillermo et al., 2024). Therefore, by integrating various relevant issues, including environmental issues, into the learning process, mathematics is not just an academic subject, but also a tool to foster critical awareness of global issues, such as the environment problem, which are increasingly urgent to address.

Building on this perspective, this research aims to respond to the current limitations in integrating Education for Sustainable Development (ESD) into formal mathematics education by developing a Hypothetical Learning Trajectory (HLT) as a practical guide. The proposed HLT is designed to help educators implement realistic mathematics learning grounded in the principles of ESD, using the issue of microplastic pollution as a meaningful and context-rich entry point. Gürbüz & Çalık, (2021) that connects mathematical modeling with environmental issues has also proven that the use of mathematical concepts to model real problems can produce relevant, applicable, and meaningful solutions.

Previous studies have demonstrated the potential of integrating environmental issues into mathematics education. Gürbüz & Çalık (2021) showed that applying mathematical modeling to environmental problems can generate relevant, applicable, and meaningful solutions. Similarly, Dariyanto & Mariana (2019) and Hartini et al. (2015) developed realistic mathematics learning designs based on environmental themes at the elementary level, proving that mathematics can be effectively contextualized through environmental concerns. While these studies provide important contributions, they mostly focus on general environmental topics and are not yet connected to a structured educational framework. This study builds on these efforts by focusing on a specific and current issue, which is microplastic pollution and by using the Education for Sustainable Development (ESD) framework to guide the learning design. Through this approach, this study aims to provide a contextually relevant and pedagogically grounded approach to integrating sustainability into mathematics learning.

METHODS

This research uses a qualitative approach with the *Design Research* (DR) method. Barab & Squire (2004) define Design Research as a methodological approaches aimed at generating new theories, products, or practices that both explain and impact learning and teaching within realistic educational settings. Specifically, this study adopts the preparation phase of design research, focusing on the development of a Hypothetical Learning Trajectory (HLT) without classroom implementation. According to Gravemeijer & Cobb (2006), the initial phase of a design research project involves the formulation of a HLT, which includes a learning goal, a learning route, and instructional tasks. While this study does not include classroom implementation, the design of the HLT was informed by theoretical and empirical literature to ensure internal coherence and potential for future application.

The preparation phase of this study included identifying the starting points of student understanding, the intended learning goals, and the development of a preliminary local instruction theory in the form of a Hypothetical Learning Trajectory (HLT) (Kaiser & Presmeg, 2019). To support this development, the researcher first classified and structured the learning objectives to establish a clear instructional focus. This was followed by the formulation of conjectures regarding students' possible learning processes, which serve as the foundation for anticipating how students might engage with and progress through the learning activities. To ensure the validity of the data, internal validity will be conducted during the research process. The stages of this research can be observed through the following chart:

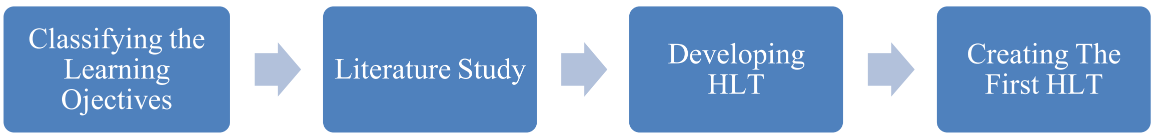


Figure 1. Research Stages

RESULTS AND DISCUSSION ← 13pt, Arial, Bold, UPPERCASE

Classifying the Learning Objectives

This research develops a series of learning activities based on the learning process conjecture which will be organized in the form of a learning trajectory called *Hypothetical Learning Trajectory* (HLT). HLT is a theoretical model for mathematics learning design that consists of three components which include learning objectives, a series of learning tasks, and hypotheses or learning process conjectures (Simon, 2020). The HLT in this study is the first version of HLT in the whole design. The HLT was developed by referring to several learning conjectures outlined in the TAL Project by Heuvel-Panhuizen (2008), which are aligned with the arithmetic operation of whole numbers at the high grade level of primary school. This version is contextualized within the issue of microplastics to foster mathematical understanding and environmental awareness in students.

In designing the HLT, a series of activities were organized sequentially. This series of activities includes calculating the estimated amount of microplastics consumed by each student with stages in the form of daily, weekly, monthly, and annual time spans. Through all of these stages, students can build and develop the concept of addition and multiplication in arithmetic operations on whole numbers up to 1,000,000 and the solution strategy in each stage, where this concept can be observed in **Figure 2**. This goal is in accordance with the Learning Outcomes (CP) of mathematics in phase C which states that students can solve arithmetic operations on whole numbers up to 100,000 (Badan Standar, Kurikulum, dan Asesmen Pendidikan, 2024).

The focus on calculating microplastic consumption serves a dual purpose. By engaging students in activities that allow them to quantify their own microplastic intake, they are encouraged to critically examine and internalize the urgency of the microplastic pollution issue. This approach fosters a deeper understanding of environmental impacts while simultaneously enhancing mathematical reasoning. Additionally, by prompting students to select effective mathematical arithmatic strategies, this design supports the development of more meaningful and applied mathematical understanding. This activity is supported by findings from Collier et al. (2023), who reported that students involved in measuring microplastics in water or soil samples demonstrated improved analytical skills and a more profound comprehension of both mathematics and environmental issues.

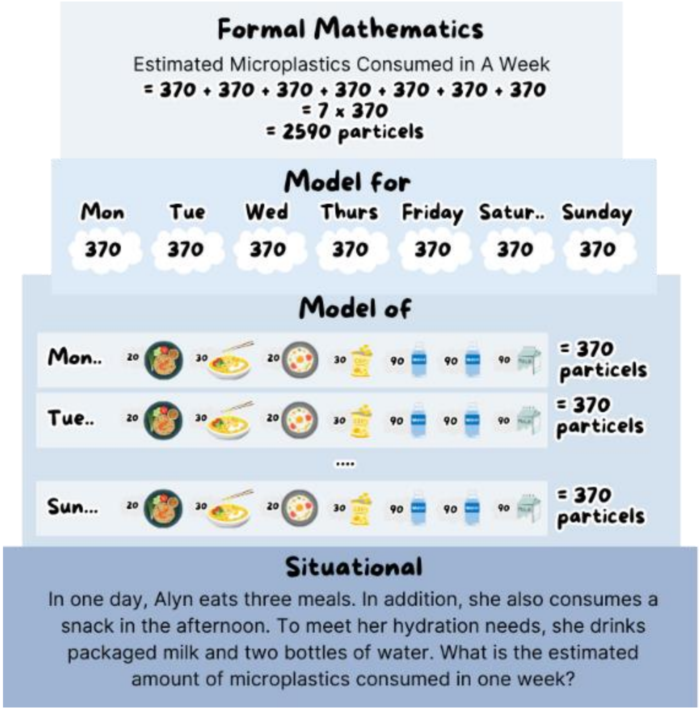


Figure 2. Ice Berg of First Mathematical Concept

In addition, the series of activities also accompanied by *Education for Sustainable Development-based* learning objectives based on the curriculum framework compiled by Osman et al. (2017) which can be seen on the table below:

Table 1. ESD Curriculum Framework for Goal 12 by Osman et al (2017)

	Knowledge and Understanding	**Skills and Applications**	**Values and Attituteds**
Primary Education	1) Sustainable and unsustainable consumption, including resource use, waste generation and disposal, and environmental and health impact 2) Further understanding of the '4 Rs' 3) Identify example or irresponsible and unsustainable consumption and production, both locally and globally	1) Distinguishing between and analysing consumer impacts and risks of different choices (e.g. discovering what products are made of, decomposition times, where waste goes). 2) Participating in recycling, compositing and other environmental schemes	1) Sense of agency, participatory capacity 2) Appreciaton of the need to reduce harm of impact and of finite resources 3) Adoption of non-wasteful behaviours (e.g. reduce packaging, use compost, seek environmentally friendly options) 4) Awareness of environmental/health risks, and benefits of safe disposal
	4) Understand impact of consumptive choices (e.g. diet)	3) Analyse carbon and methane impacts of diet and food purchasing	5) Informed purchasing (product lifecycle implications)

	Knowledge and Understanding	Skills and Applications	Values and Attituteds
	5) Participatory learning 6) Explore how technology can be harnessed and used to support responsible consumption and production 7) Calculate and compare Ecological Footprints	behaviour ***4) Food chain analysis (e.g. family food purchasing behaviour and impacts)*** 5) Understand the challenges facing the planet and the need for more responsible consumption and production patterns 6) Understand how fast resources are consumed and waste is generated	***6) Consumer awareness and commitment to sustainable choices*** 7) Prepared to take action to bring about change and reduce the Ecological Footprints

Based on the curriculum framework for Education for Sustainable Development at the primary level, the learning objectives of this research activity have been developed to align with three core components: knowledge and understanding, skills and application, and values and attitudes. These components serve as the foundation for designing learning experiences. By aligning the activity with these components, the learning design not only addresses mathematical competencies but also cultivates holistic environmental awareness among students.

The knowledge and understanding component focuses on helping students comprehend the influence of sustainable and unsustainable consumptive choices, particularly in relation to environmental and health impacts. In this activity, students will be guided to explore how everyday decisions, such as food consumption, can contribute to microplastic pollution and resource depletion. This reflects key curriculum goals, such as recognizing the impact of consumption.

The skills and application component emphasizes students' ability to analyze the presence and pathways of microplastics in the human food chain. By investigating real-life contexts, such as their daily food intake, students develop data analysis skills. This hands-on approach also supports curriculum targets such as analyzing consumer impacts, participating in environmental schemes, and applying scientific reasoning to everyday phenomena. This dimension is particularly supported through a quantitative analysis, specifically by estimating microplastic consumption across various time spans (daily, weekly, monthly, and yearly). This estimation process targets mathematical learning goals, especially in the development of arithmetic operations involving whole numbers, as outlined in the Phase C mathematics curriculum.

The values and attitudes component is addressed by fostering a sense of environmental responsibility, encouraging consumer awareness, and promoting a commitment to making sustainable choices. Through reflection and participatory learning, students are expected to internalize the importance of reducing waste, making informed purchasing decisions, and taking action to reduce their ecological footprint. To support deeper reflection, students are encouraged to compare their results with those of their peers or alternative datasets. This comparison process necessitates the introduction of sorting whole numbers, which remains aligned with the mathematical competencies described in Phase C where the students are expected to be able to sort whole numbers up to 1,000,000 (Badan Standar, Kurikulum, dan Asesmen Pendidikan, 2024). The integration of this concept enhances students' ability to interpret, compare, and draw conclusions from numerical data, reinforcing both environmental awareness and mathematical understanding. This connection between curriculum goals and mathematical reasoning is visually represented in the iceberg figure 3 below.

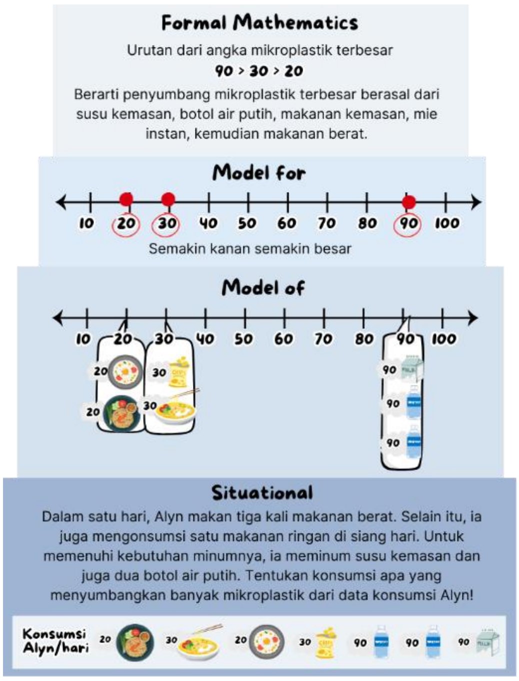


Figure 3. Ice Berg of Second Mathematical Concept

Building on this foundation, the intertwining of the two mathematical concepts which is estimation and sorting of whole numbers not only strengthens students' numeracy skills but also deepens their engagement with sustainability issues grounded in real-life contexts. Rather than treating these concepts in isolation, their integration within the learning activity allows students to meaningfully connect quantitative reasoning with reflective judgment. For instance, estimating the amount of microplastics consumed over time provides a tangible sense of scale, while sorting numerical data enables students to compare individual and collective consumption patterns, thus promoting informed decision-making. This intertwinement enhances the overall educational impact by embedding mathematical learning within ethical, environmental, and spiritual dimensions, ensuring that the activity is not only cognitively enriching but also value-driven in line with both ESD Framework.

Based on the explanation above, the relation between the mathematics concepts and ESD in the activity design can be seen in the table below.

Table 2. Relation between Mathematics Concept and ESD Component on Learning Design

Activity	Mathematics Concepts	ESD Components
	Introduction Activity	
Pre-activity: Understand Microplastics	Recognize quantitative data on the issue of microplastics	Knowledge and understanding: Understand impact of consumptive choices
	Core Activities	
Activity 1: Calculate the amount of microplastics consumed in one day	Perform addition operations on whole numbers	Skill and application: Food chain analysis (e.g. family food purchasing behaviour and impacts)
Activity 2-4: Calculate the amount of microplastics consumed in over one week, one month, and one year	Perform addition and/or multiplication operations on whole numbers	
	Reflection Activity	
Activity 5: Reflect on the estimation of microplastic consumed	Ordering whole numbers up to 1.000.000	Values and Attitudes: Consumer awareness and commitment to sustainable choices

Developing Hypothetical Learning Trajectory

The HLT will elaborate activity 1 to activity 5 into four sections which include learning objectives, starting points, intended activities and conjectures from the learning process to design the HLT based on some of previous studies. The pre-activity part is not discussed in the HLT because it does not contain mathematical conjectures, and it is only intended as a process of introducing the context of environmental issues in this learning activity, but it will still be explained how the pre-activity process takes place. This is in accordance with the opinion of Bakker (2018) which states that there is a difference between HLT and instructional sequences. The learning trajectory or HLT refers to a hypothetical framework predicting how students' understanding of mathematics might evolve, while the instructional sequence refers to the design of the order and structure of tasks or lessons intended to support this development. In this research, the instructional sequences starts from the introduction to reflection, which includes pre-activities and activities 1 to 5. Meanwhile, the learning trajectory starts from activities 1 to 5 where the development of students' understanding of mathematics objectives begins to the end.

The starting point describes the students' prior understanding or the students' basic knowledge needed to do the learning activity (Mariana, 2009). In the intended activities, it will be explained in detail related to activities that support the learning process to achieve learning objectives. And the learning process conjecture section will explain the possible responses of students to the given set of activities.

Pre-Activity: Recognizing Microplastics

Intended activity: The activity begins by providing information and data related to the urgency of the microplastics issue through a small discussion between researchers and students before watching a learning video entitled *Is it true that we consume plastic?* which provides information about microplastics that enter the human body every day through food, drinks, and air. The researcher then start further discussion with a mathematical question, '*If you consume a small amount of microplastic particles daily, is it still a small amount if it happens everyday?'.* This question aims to direct students to quantitative thinking.

Activity 1: Calculate The Amount of Microplastics Consumed in One Day

Learning objectives: The main objectives of this activity are the students to be able to (1) perform addition operations on whole numbers and, (2) analyze microplastics in the daily human food chain

Starting point: Students already have experience in completing addition and multiplication operations of whole numbers in simple situations. In addition, students also need to have the ability to estimate their daily consumption.

Intended Activity: After students have an initial awareness of the presence of microplastics in their daily lives in the pre-activity, they are invited to estimate the amount of microplastics consumed in a day to prove the information in the video. This estimation process was carried out by collecting data of the microplastics consumption of each students through food, beverage and air stickers that represent the things that enter their bodies. These stickers are accompanied by the amount of microplastic particles contained in them.

In determining the amount of microplastic particles, the amount of microplastic is used by classifying consumption into several types based on a literature review by Cox et al. (2019). The data shows that bottled water consumption generates 174-349 microplastic particles (MP) in each day, while tap water only generates 8-16 particles in each day depending on age group and gender. As for air, children breathe from 97 to 110 microplastic particles in a day. Based on the limitations of previous research on microplastic content in various foods such as beef, poultry, dairy products, grains, and vegetables, the estimation of MP consumption by humans is still partial. Humans are also estimated to consume between 13,731 and 68,415 MP particles in a year from airborne particles. From this range, a *mean of* 41,073 MPs was taken, which was obtained by adding the lower and upper bounds of the estimate and dividing by two. This is equivalent to about 112 particles daily. To make the calculations easier for students at this stage, the numbers are simplified and the middle value is taken, i.e. tap water is assumed to contain 10 microplastic particles/liter, while bottled water is assumed to contain 90 particles/liter. For inhaled air, it was estimated that all total incoming air carried 110 particles. It is also estimated that household food contains about 60 particles/day or 20 particles/meal. Meanwhile, foods that are packaged or contain plastic elements, such as instant noodles and snacks, are estimated to contribute about 30 MP. From the consumption categories and the amount of microplastics, the following stickers were made for students' consumption:

Figure.4 Consumption Stickers

After recording their daily consumption with the stickers, students were asked to estimate the amount of microplastic particles entering their bodies based on the data.

Conjecture: In the process of estimating the number of microplastic particles consumed, students are expected to use addition operations with various solution strategies. Some students are likely to use the method of counting one by one, for example from 50, 51, 52 and so on to 70, then from 70 to 110, and so on. Another strategy that may also appear the most is addition using the stacking down method. Students may apply the concept of the *zero rule* (Heuvel-Panhuizen, 2008). Another conjecture that may arise is in the data processing process, where students are expected to group their consumption data based on the source categories such as food, beverages and air either in the form of tables or list.

Activity 2: Calculate The Amount of Microplastics Consumed in One Week

Learning objectives: Students are expected to be able to (1) perform addition or multiplication operations on whole numbers up to 10,000 and (2) analyze microplastics in the daily human food chain.

Starting point: Students already have experience of completing addition and multiplication operations of whole numbers in simple situations. In addition, students should also have found the estimated microplastics consumed in one day in the previous activity.

Intended Activity: Continuing the previous activity, students have to extend their understanding of arithmetic operations on whole numbers by calculating the estimated consumption of microplastics over a period of time. This activity will be carried out over the next three activities, but at this stage, students will focus on calculating the estimate within one week only. This activity can be started by the teacher linking the estimation of microplastics consumed during one day from the previous activity, '*If in one day, we get so many results. Then, how many microplastics do we consume for one week?*". Students are allowed to discuss in small class groups to strategize. In this process, it is important to encourage students to choose the calculation strategy that is most suitable and efficient for them, so that students are able to explore in determining the solution strategy. Teachers need to emphasize that the process and strategies used are as important as the final answer, so they need to convey that there are many possible valid solution strategies.

Conjecture: In doing this activity, students are likely to use different approaches. Some students may choose to calculate daily consumption separately for each day of the week (Mutaqin et al., 2019), which is then summed up using the addition operation. This addition can be completed with various strategies ranging from counting one by one, stacking down or the zero rule. Meanwhile, other students may recognize repeating number patterns and use multiplication operations, either by stacking down, splitting numbers, or *zero rule* strategies to simplify the counting process.

Activity 3: Calculate The Amount of Microplastics Consumed in One Month

Learning Objectives: Students are expected to be able to (1) perform addition or multiplication operations on whole numbers up to 100,000 and, (2) analyze microplastics in the daily human food chain.

Starting Point: Students have previously obtained the results of estimating microplastics consumed during one day or one week.

Intended Activity: In this activity, students extend their estimation to a longer period of time, which is in one month. As the period of time increases, so does the number. The activity can be started by inviting student to reflect on their previous daily and weekly estimates. The discussion is directed at asking students to imagine the relationship between weeks and months and to develop a sequence of solution steps that they consider efficient. The teacher does not give the method directly, but asks how students determine their calculation steps. The emphasis in this activity is on giving students space to compare different approaches from the context, as part of a developing mathematical thinking process.

Conjecture: In the process of estimating consumption of microplastics in a month, it is likely that students will show several approaches in completing this activity. If in the calculation of weekly time estimation, it is still possible for students to do repeated addition up to seven times. However, it is expected that students will begin to realize that calculating the amount of microplastic consumption in one month for 30 days using the addition method will be time-consuming and risk causing calculation errors. Therefore, most students are likely using multiplication strategies, especially through the stacking down method, the number splitting technique, or applying the zero rule to simplify the counting process. Eventhough the possibility of students' answers using addition operations still remains.

Activity 4: Calculate The Amount of Microplastics Consumed in One Year

Learning Objectives: Students are expected to be able to (1) perform addition or multiplication on whole numbers up to 1,000,000 and (2) analyze microplastics in the daily human food chain

Starting point: Students have previously obtained the results of estimating microplastics consumed during one day, one week and one month.

Intended Activity: Students continue their exploration process by estimating the amount of microplastics consumed over a longer period of time, i.e. one year. The teacher encourages students to sequence their steps logically and explain the reasoning behind the sequence. In this process, students should consider efficiency of the strategy. Same as previous activity, the teacher does not lead to one particular method, but rather facilitates a discussion that exposes a range of possible approaches that make sense based on students' own understanding.

Conjecture: In calculating the estimated consumption of microplastics in one year, some students may choose to add up the estimated consumption of microplastics from each month, from January to December, using addition or arranging the data in tables or rows. However, other students may realize that this is inefficient and start using the multiplication strategy as a faster solution. Some multiply the number of months (12) by the total microplastics in a month, or multiply the number of days in a year (365) by the daily consumption. In this process, various calculation strategies are likely to emerge, such as downward stacking multiplication, number splitting techniques, or application of the *zero rule.*

Activity 5: Reflect on The Estimation of Microplastic Consumed

Learning objectives: In the reflection activity, students are expected to be able to (1) order whole numbers up to 1,000,000 and (2) foster consumer awareness and commitment to sustainable choices.

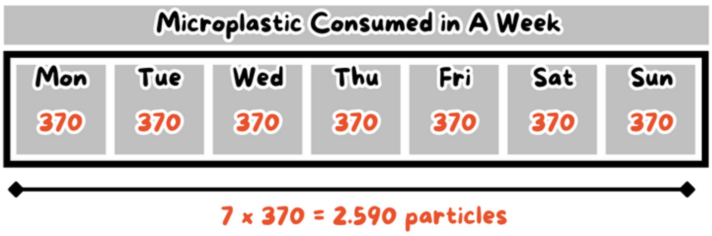
Starting point: Students should have previously know the basic concept of sorting whole numbers by understanding the place value of numbers. In addition, students should also have completed the calculation of the estimated microplastics consumed in one year in the previous activity.

Intended Activity: This reflection stage is the last series of activities to calculate the estimated microplastic consumption. Students will be asked to collect data on the estimated microplastic consumption of their classmates, then sort the numbers from the smallest to the largest. From the results of this data sorting, students are then asked to reflect on these results by answering several questions on the worksheet in the form of '*Who consumes the least microplastics? Why is this so?'* and *'What should be done to reduce microplastic consumption?'*

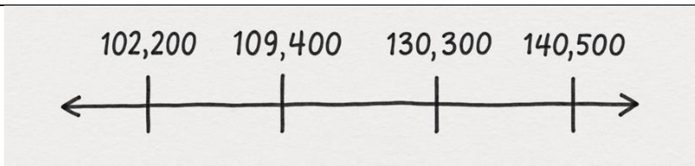
Conjecture: Students are likely to use different ways to sort the data. Most may draw a number line to position the values of each individual's estimated microplastics. In the process of comparing, students may start to notice place values that make up a large number, such as distinguishing between thousands, tens of thousands and hundreds of thousands. This strategy shows their ability to recognize the place value of numbers and accuracy in comparing data.

From the description of the activity design above, the HLT composition which is the first version in this study is obtained in table below.

Table 3. Hypothetical Learning Trajectory

Activity	Learning Objectives	Conjectures
Activity 1: Calculate the Amount of Microplastic Consumed in One Day	(1) Perform addition operations on whole numbers (2) Analyze microplastics in the daily human food chain	(1) Students process their consumption data by grouping it based on the category of microplastic sources consumed.  (2) Students use addition operations with the following strategies: 1. One by one counting strategy 2. Stacking down addition strategy 3. Using the zero rule concept
Activity 2: Calculate the Amount of Microplastic Consumed in One Week	(1) Perform addition or multiplication operations on whole numbers up to 10.000 (2) Analyze microplastics in the daily human food chain	(1) Students calculate consumption with addition operations on each day of the week using one of the strategies. (a) One by one counting strategy (b) Stacking down addition strategy (c) Using the zero rule concept  (2) Students recognize the pattern of microplastic numbers consumed repeatedly for 7 days and use multiplication operation with one of these stragegies: (a) One by one counting strategy (b) Downward stacking addition strategy (c) Using the concept of zero rule

Activity 3: Calculate the Amount of Microplastic Consumed in One Month	(1) Perform addition or multiplication operations on whole numbers up to 100.000 (2) Analyze microplastics in the daily human food chain	(1) Students calculate consumption with addition operation on each day of the week using one of these strategies: (a) One by one counting strategy (b) Stacking down addition strategy (c) Using the zero rule concept (2) Students recognize the number pattern of microplastics consumed repeatedly for 30 days and use multiplication operation with these strategies: (a) Downward stacking multiplication strategy (b) Number separation strategy (c) Using the zero rule concept
Activity 4: Calculate the Amount of Microplastic Consumed in One Year	(1) Perform addition or multiplication operations on whole numbers up to 1.000.000 (2) Analyze microplastics in the daily human food chain.	(1) Students calculate consumption with addition operations on each day of the week using one of these strategies: (a) One by one counting strategy (b) Stacking down addition strategy (c) Using the zero rule concept  (2) Students recognize the pattern of microplastic numbers consumed repeatedly for 12 months and use multiplication operations with one of these strategies: (a) Downward stacking multiplication strategy (b) Number separation strategy (c) Using the zero rule concept (3) Students recognize the number pattern of microplastics consumed repeatedly for 360 days and use multiplication operations with one of these strategies: (a) Downward stacking multiplication strategy (b) Number separation strategy (c) Using the zero rule concept
Activity 5: Reflect on the Estimation of	(1) Order Whole Numbers up to 1.000.000 (2) Foster consumer awareness	(1) Students observe the place value of numbers in sorting whole numbers (2) Students use a number line in sorting whole numbers

Microplastic Consumed	and commitment to sustainable choices	

CONCLUSION

This research designed a sequence of learning activities based on a Hypothetical Learning Trajectory (HLT) that integrates mathematical concepts with Education for Sustainable Development (ESD), using the real-world issue of microplastic pollution. The activities aim to develop students' skills in arithmetic operations, especially addition and multiplication of whole numbers up to 1,000,000) while fostering awareness of sustainable consumption. Here's a summary of each activity and its contribution:

1. Pre-Activity: Recognizing Microplastics
   Students are introduced to the issue of microplastics through video and discussion. This stage builds students' awareness and sets the stage for quantitative thinking.
2. Activity 1: Calculate the Amount of Microplastic Consumed in One Day
   Students estimate the number of microplastic particles they consume in one day using data stickers. This involves addition and introduces the idea of quantifying environmental impact.
3. Activity 2: Calculate the Amount of Microplastic Consumed in One Week
   Building on daily data, students extend their understanding to weekly estimates using either repeated addition or multiplication. This supports strategic thinking in problem-solving.
4. Activity 3: Calculate the Amount of Microplastic Consumed in One Month
   Students estimate microplastic intake over a month. With larger numbers, they are encouraged to use more efficient multiplication strategies, fostering deeper mathematical reasoning
5. Activity 4: Calculate the Amount of Microplastic Consumed in One Year
   This final estimation pushes students to handle numbers up to 1,000,000, reinforcing multiplication strategies and scaling up their understanding of environmental impact.
6. Activity 5: Reflection and Comparison
   Students compare their results and reflect on consumption patterns. This activity involves sorting whole numbers and promotes critical thinking, environmental responsibility, and value-based learning.

Each activity integrates key mathematical concepts with ESD competencies—knowledge, skills, and values—to support students' holistic development as numerate and responsible future citizens. Those three core learning outcomes are (1) Knowledge and Understanding of the impacts of consumption; (2) Skills and Application through data collection and mathematical analysis; and (3) Values and Attitudes, by fostering reflection and ethical responsibility.

In conclusion, this research successfully demonstrates how mathematical learning can be embedded within sustainability issues. The HLT-based learning trajectory enables students to master arithmetic operations, including building an understanding that multiplication is another form of repeated addition. It also cultivates a sense of agency and responsibility toward the environment and their communities.

REFERENCES

Aprilianti, R. (2024). *Rekam Jejak Mikroplastik*. CV. Global Aksara Pers. https://globalaksarapers.com/product/rekam-jejak-mikroplastik/

Badan Standar, Kurikulum, dan Asesmen Pendidikan. (2024). *Keputusan Kepala Badan Standar, Kurikulum, dan Asesmen Pendidikan Nomor 032/H/KR/2024 tentang Capaian Pembelajaran Pada Pendidikan Anak Usia Dini, Jenjang Pendidikan Dasar, dan Jenjang Pendidikan Menengah pada Kurikulum Merdeka* (No. 032/H/KR/2024; pp. 142–146). Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi. https://kurikulum.kemdikbud.go.id/file/1718471412_manage_file.pdf#page=132.42

Bakker, A. (2018). *Design Research in Education: A Practical Guide for Early Career Researchers* (1st ed.). Routledge. https://doi.org/10.4324/9780203701010

Barab, S., & Squire, K. (2004). Design-Based Research: Putting a Stake in the Ground. *Journal of the Learning Sciences*, *13*(1), 1–14. https://doi.org/10.1207/s15327809jls1301_1

Barwell, R. (2018). *Some Thoughts on a Mathematics Education for Environmental Sustainability*.

Cox, K. D., Covernton, G. A., Davies, H. L., Dower, J. F., Juanes, F., & Dudas, S. E. (2019). Human Consumption of Microplastics. *Environmental Science & Technology*, *53*(12), 7068–7074. https://doi.org/10.1021/acs.est.9b01517

Dariyanto, D. K., & Mariana, N. (2019). Penelitian Multi Paradigma: Matematika Peduli Sampah Dengan Pendekatan Pmri Di Kelas V SDN Jambangan I/413 Surabaya. *Jurnal Pendidikan Guru Sekolah Dasar*, *07*(03), 2985–2995.

Drijvers, P. (2022, February 11). *Realistic Mathematics Education (RME)—An introduction*. https://www.uu.nl/sites/default/files/2022-02-11Summerschoolteaser-RMEcontexts-Drijvers.pdf

Gravemeijer, K., & Cobb, P. (Eds.). (2006). Design research from a learning design perspective. In *Educational design research*. Routledge.

Guillermo, J. C. L., Guitton Lozano, E., Pérez Marín, J. L., Barreda Fachin, M. J. C., Peña Pasmiño, R. W., & Yon Delgado, J. C. (2024). *Hans Freudenthal's realistic mathematical theory: Didactics and research paradigms* (2nd ed.). Editorial Mar Caribe. https://doi.org/10.70288/emc.9789915970660

Gürbüz, R., & Çalık, M. (2021). Intertwining Mathematical Modeling With Environmental Issues. *Problems of Education in the 21st Century*, *79*(3), 412–424. https://doi.org/10.33225/pec/21.79.412

Hakim, N., Apriyanto, A., Mardiati, M., & Sitepu, E. (2024). Implementation of the Realistic Mathematics Education (RME) Approach in Geometry Learning in Secondary Schools. *Aksioma Education Journal*, *1*(3), 17–30. https://doi.org/10.62872/rgn3w339

Hartini, S., Somakim, & Kesumawati, N. (2015). Desain Pembelajaran Materi Pengolahan Data Menggunakan Konteks Adiwiyata Melalui Pendekatan PMRI di SD. *Jurnal Inovasi Sekolah Dasar*, *2*(1), 9–18.

Heuvel-Panhuizen, M. van den (Ed.). (2008). *Children Learn Mathematics: A A Learning-Teaching Trajectory with Intermediate Attainment Targets for Calculation with Whole Numbers in Primary School*. Brill | Sense. https://doi.org/10.1163/9789087903954

Kaiser, G., & Presmeg, N. (Eds.). (2019). *Compendium for Early Career Researchers in Mathematics Education*. Springer International Publishing. https://doi.org/10.1007/978-3-030-15636-7

Kanandjebo, L. N. (2024). Mathematics as a driver for sustainable development: Pre-service teachers' perspectives on awareness, challenges, and implications for teacher training. *Interdisciplinary Journal of Education Research*, *6*, 1–17. https://doi.org/10.38140/ijer-2024.vol6.26

Khairunisa, Utami, W. Z., Lestari, N., & Hidayati, D. (2024). Implementasi Model Pembelajaran Matematika Realistik (PMR) dalam Meningkatkan Pemahaman Matematis Siswa Kelas VI MIN 2 Kota Mataram. *Populer: Jurnal Penelitian Mahasiswa*, *3*(4), 30–36. https://doi.org/10.58192/populer.v3i4.2651

Lestari, S. A. P., Nurapriani, F., & Kusumaningrum, D. S. (2024). Integrating Sustainable Development Principles in Learning Mathematics to Stimulate Sustainable Skills in Future Generations. *Jurnal Rekayasa Sistem Industri*, *13*(1), 1–10. https://doi.org/10.26593/jrsi.v13i1.7167.1-10

Li, H.-C., & Tsai, T.-L. (2022). Education for sustainable development in mathematics education: What could it look like? *International Journal of Mathematical Education in Science and Technology*, *53*(9), 2532–2542. https://doi.org/10.1080/0020739X.2021.1941361

Mariana, N. (2009). *Design Research in Geometry Education Developing Spatial Abilities In First Grade Children* [Freudenthal Institute Utrecht University]. https://www.fisme.science.uu.nl/en/impome/theses_group_2007/thesis_Neni.pdf

Mutaqin, E., Asyari, L., & Muslihah, N. (2019). Hypothetical Learning Trajectory: Whole Number Multiplication in Primary School. *Proceedings of the Proceedings of the 1st International Conference on Business, Law And Pedagogy, ICBLP 2019, 13-15 February 2019, Sidoarjo, Indonesia*. Proceedings of the 1st International Conference on Business, Law And Pedagogy, ICBLP 2019, 13-15 February 2019, Sidoarjo, Indonesia, Sidoarjo, Indonesia. https://doi.org/10.4108/eai.13-2-2019.2286153

Osman, A., Ladhani, S., Findlater, E., & McKay, V. (2017). *Curriculum Framework for the Sustainable Development Goals*. Commonwealth Secretariat. https://doi.org/10.14217/ComSec.1064

Simon, M. (2020). Hypothetical Learning Trajectories in Mathematics Education. In S. Lerman (Ed.), *Encyclopedia of Mathematics Education* (pp. 354–357). Springer International Publishing. https://doi.org/10.1007/978-3-030-15789-0_72

Su, C. S., Díaz-Levicoy, D., Vásquez, C., & Hsu, C. C. (2023). Sustainable Development Education for Training and Service Teachers Teaching Mathematics: A Systematic Review. *Sustainability*, *15*(10), 8435. https://doi.org/10.3390/su15108435

Zulu, M., & Sanjigadu, S. (2024). *Exploring the Role of Professional Development towards Capacitating Mathematics and Science Teachers for Education for Sustainable Development (ESD)*. 32nd Annual Conference of the Southern African Association for Research in Mathematics, Science and Technology Education.