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The Role of Experiencing Self-Efficacy When Completing Tasks—Education for Sustainable Development in Mathematics

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Abstract: A wide variety of requirements can be placed on tasks that deal with education for sustainable development in mathematics lessons. They should be as authentic as possible, use real problems as the mathematical learning material, and stimulate action, among other qualities. This article discusses the role of self-efficacy and the experience of self-efficacy when working on modelling tasks that are geared towards a sustainable future. High school students in Germany worked in a STEM learning environment on different aspects of climate change and species extinction, including plastic waste, recycling, rainforests, and their deforestation. These aspects were analysed from a geographical, biological, physical, and mathematical perspective. In mathematics, specifically, tasks were used to address the learners' self-efficacy. After completing the tasks, a questionnaire was distributed to assess the interest and motivation of the learners. The results show that even a slightly different use of self-efficacy, whether by focusing on what has already been achieved (sustainable successes that promote positive emotions) or on what can still be achieved, can influence the learners' interest in completing the tasks. The learners' experience of self-efficacy seems to have a positive influence on their willingness to solve tasks. Additionally, the results indicate a complex relationship between motivation and interest on the one hand and self-efficacy on the other.

Keywords: self-efficacy; STEM; climate change; interest; motivation

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1. Introduction

In 2015, the United Nations formulated 17 Global Goals to ensure a sustainable future. These Sustainable Development Goals address different interconnected dimensions of sustainability, from the call for 'zero hunger' to 'quality education'. In response, different local concepts were developed (e.g., in Germany, 'School of the Future', see www.sdz.nrw.de, or 'School of Sustainability', see www.unesco.de/bildung/bne-akteure/schule-der-nachhaltigkeit-0 (accessed on 7 April 2025)) to achieve these goals with learners.

The significance of such demands and initiatives is underlined by the findings of climate studies, which indicate that technological innovations alone can no longer adequately address the current climate crisis and that transformative changes in human behaviour are imperative (see, for instance, the climate report commissioned by the House of Lords' Environment and Climate Change Committee [1] or others in [2]).

The discussion of suitable content and the training of necessary skills for a sustainable life is therefore not only an essential part of general education in mathematics or STEM lessons, but also a necessity for future life (cf. [1,3]). Showing learners the consequences for their own future and guiding them to act accordingly implies that the topic is not only used

to solve mathematical problems but is itself taken seriously and discussed. In addition to the mathematical processes, it is important to reflect on different concepts of sustainability to encourage a transfer to one's own lifestyle. In a similar manner, the core competencies "Recognising, evaluating, and acting" are described in the 'Orientation Framework for Global Development' [4]. To use the words of Winter [5], "factual arithmetic as learning material" is of central importance when working on ESD (Education for Sustainable Development)-related tasks.

2. Theoretical Background

2.1. Selected Didactic Approaches for Integrating ESD into the Classroom

In addition to various tasks (see, for example, the collection [6]), the didactic literature contains diverse approaches to integrate ESD in the classroom. Wilhelm, for example, focuses on "ESD-Fermi tasks" [7]. A classic example of this type of task is the question: "How many piano tuners are there in Chicago?" The attainment of a precise solution to such a task is, in all likelihood, unfeasible. The approach adopted involves the formulation of assumptions and the subsequent calculation of approximate solutions [8]. By using Fermi tasks, for example, it is possible to determine whether the distance from the earth to the moon could be covered 25 times with the receipts produced annually by the introduction of compulsory receipts in bakeries [7]. Additionally, the task's connection to the learners' reality can be increased by using newspaper cuttings or contemporary media such as TikToks or Instagram posts.

Meyer adopts a different approach in the 'STEM goes ESD' project, endeavouring to convey interdisciplinary mathematical, physical, biological, and chemical backgrounds for ESD contexts while at the same time focusing on the three steps of development, reflection, and transfer [9]. The interdisciplinary foundations and varied contexts of ESD content itself require introductory texts or videos to achieve these steps (e.g., the importance of CO_2 for the climate should be addressed to understand the content of compensation for air travel through trees (example in [10])).

In the project 'The Future We Want' [11], the concept of solution-oriented didactics is presented, which was developed by Hoffmann [12] for geography lessons. While ESD is often viewed from a negative perspective (e.g., negative effects of global warming or species extinction), this project focuses on positively framed goals: if, for example, a clean sea is desired, ways to clean up the sea should be developed. This approach entails the proactive identification of viable solutions to environmental challenges, thereby offering a proactive approach to achieving the desired future state.

These presented approaches to the thematic incorporation of ESD in classroom settings differ in their methodology. Rather than providing a comparative analysis, it is more appropriate to integrate these approaches in a holistic manner. Both the focus on modelling in mathematics lessons—regardless of whether self-assessed values are incorporated—and the emphasis on personal involvement in processes of development, reflection, and transfer are already established features of the aforementioned approaches. The solution-oriented approach from geography underlines the efficacy of learners' actions. A core objective of the present study, upon which this article is based, was to analyse this self-efficacy for ESD action regarding its consequences for school mathematics.

In the present study, the presented approaches were interwoven: the benefits of different, intensively introduced contexts, the use of modelling tasks, and the avoidance of a negative future perspective. The latter was achieved by addressing self-efficacy.

2.2. Self-Efficacy as a Characteristic in Mathematics Lessons

Multiple studies (e.g., [13–15]) show that climate change has a negative impact on the mental health of students. One approach to counteract here is to highlight not only the negative consequences, but also the potential that environmentally conscious behaviour brings. In the scientific literature, the concept of self-efficacy is prominently used in this context. Self-efficacy is commonly understood as an expectation, whereby the perceived self-efficacy refers to "beliefs in one's capabilities to organize and execute the courses of action required to manage prospective situations" [16] (p. 2).

In the field of mathematics education, the notion of self-efficacy has been a subject of investigation by numerous researchers (e.g., [17–20]) who predominantly conceptualised it as a component of learners' expectations regarding their ability to successfully master mathematical tasks. The learner's own interpretation of previous experiences, the self-assessment of their own abilities, and potential success play an important role, insofar as these help to predict future events [21,22]. However, in the context of sustainable development, self-efficacy is conceptualised a little bit differently: Expectations are not only linked to one's own successes, but also to a positive impact on the environment (e.g., [23]). Strong self-efficacy in the context of sustainable development not only raises awareness of the effects of environmentally friendly actions but also increases the motivation to carry out these actions [23].

Regarding maths self-efficacy, items such as the following are typically used in mostly quantitative studies in order to measure this expectation:

- "In maths, I am confident that I can understand even the most difficult material".
- "I am confident that I can master the skills taught in maths" (both [17,18]).
- "If I try hard, I can do all the maths homework" [24].

These items demonstrate that self-efficacy in mathematics is associated with expectations, including confidence in comprehending lesson content, successfully completing homework (and examinations), and proficiently mastering mathematics skills. The most significant source of mathematics self-efficacy is the 'experience of success', encompassing the interpretation of prior academic achievements in mathematics [22]. In addition to 'physiological or emotional states' and 'vicarious experiences', other influential factors include 'social beliefs' [25]. Social beliefs, such as targeted encouragement from teachers, parents, or peers, have been shown to boost learners' confidence, although negative comments usually have a greater negative impact on self-efficacy in mathematics than positive feedback [20]. The learners' assessment of their self-efficacy influences, among other things, their propensity to dedicate effort to specific tasks and their ability to persevere in the face of challenges. Empirical evidence has demonstrated the significance of self-efficacy for learners' performance in this context, and there is a consensus that self-efficacy serves as a robust predictor of mathematics performance [20].

2.3. Self-Efficacy in the Context of Sustainability

In the context of ESD, self-efficacy is conceptualised in a more expansive manner. It entails more than confidence in one's own competence; it also encompasses the conviction that one's actions have a positive impact on the world. Confidence in one's own environmental self-efficacy plays a decisive role in environmentally conscious behaviour among young people, and having a positive environmental impact is possible through a combination of active engagement and conscious renunciation [26]. A notable example of active engagement can be found in the practice of waste separation, where learners contribute directly to waste avoidance and gain first-hand experience of the effectiveness of their own actions. This phenomenon can be discussed in a classroom setting, facilitating a deeper understanding of the subject matter. Similarly, as an example for renunciation,

refraining from using plastic straws or bags when shopping at supermarkets can also contribute to sustainability. These actions are advised to the individual as part of the social community, through which the individual can in turn experience their self-efficacy in the context of sustainability.

The particular importance of self-efficacy in the course of sustainability can also be derived from the context of motivation: One condition for motivation is interest [18,27,28]. Empirical studies have been conducted to demonstrate that cognitively active learners are more inclined to be interested [28]. While the term motivation, on the other hand, is primarily related to an activity, interest is more related to an object or a person [28]. "One is motivated to learn" (motivation) or "one is interested in something or someone" (interest) [29] (p. 61; translated by the authors). "Interest is the relationship between the person and the object of learning" [28] (p. 77). Hoffmann's approach mentioned above aims to address this interest through the desired future goals. The present article examines the extent to which engaging with experiences of efficacy of one's own actions in relation to aspects of sustainability can promote learners' interest in mathematics lessons.

As the conviction that positive change is possible can also play a central role in the expectation of self-efficacy in the context of sustainability, successes such as the global ban on CFCs and the resulting reduction in the hole in the ozone layer strengthen confidence in the collective impact of human endeavour. The current experience of self-efficacy and the expectation of self-efficacy are therefore not independent of each other. Both can be described as individually positive aspects in the course of current crisis situations. Connected herewith [28,29] describes an 'emotionally positive experience of an object', which includes pleasant feelings such as joy, as an aspect of interest.

The aim of the study was to analyse the role of self-efficacy in the context of sustainability when solving mathematical tasks. The research question, accordingly, is as follows: How does a various use of self-efficacy in the sense of sustainable development influence students' interest and motivation when working on modelling tasks related to sustainability in mathematics lessons?

2.4. Tasks on Sustainable Development in Maths Lessons

The worksheets utilised in this study are available in the Appendices A and B, comprising a total of four worksheets centred around two subjects: packaging waste (cf. Appendix A) and rainforest deforestation (cf. Appendix B). Each of these subjects was addressed in both a rather positive and a rather negative formulation in terms of self-efficacy. The disparities between these versions were intentionally minimalized to ascertain whether even slight variations in formulation could potentially influence the learners' motivation to complete the worksheets. The alterations made between the different versions are marked in the tasks (see Appendices A and B).

The more positively worded versions focus on positive changes that have already taken place, with one worksheet focusing on the planned reduction of plastic in product packaging and the other on the reduction in meat consumption that has taken place in Germany.

In contrast, the more negative versions (i.e., tasks that scarcely address self-efficacy or do not address it at all) accentuate the necessity of taking action to address the situation and its consequences. For instance, the term 'deceptive packaging' is used in one worksheet as part of the 'Packaging' task. The packaging, which was optimised as part of an extreme value task, was awarded the 'Cheat pack of the year' prize. As part of the 'Rainforest' task, meat consumption in Germany continues to be a major issue.

In order to facilitate the recognition of the significance of self-efficacy by the students, it was necessary to devise tasks that were relatively text heavy. In Winter's [5] words, this approach also serves to make factual arithmetic a learning objective.

2.5. Methodological Remarks

The tasks were utilised in three mathematics courses at qualification level II at two different schools (two advanced courses and one basic course). A total of 45 students participated in the study. The students completed one version of each of the two worksheets (either more positive or more negative in terms of self-efficacy). The students who received the more positive version of worksheet A received the more negative version of worksheet B and vice versa.

In order to record the acceptance of the tasks from the learners' perspective, some statements from the categories of interest and motivation from PISA (Programme for International Student Assessment; [30]) were taken and reformulated for reflecting the worksheets. For example, the statement "I am interested in further exploring the topics covered in maths lessons myself" was changed to "I am interested in further exploring the topic covered during the worksheet myself". Specifically, the following items were included in the study:

1. I am interested in what I have learned with the worksheet.
2. I was bored while working on the worksheet.
3. I worked on the worksheet because I enjoyed it.
4. I like the fact that I was able to discover something myself while working on the worksheet.
5. I wish I hadn't had to do the worksheet.
6. It was important to me to solve the worksheet, even if it had taken longer.
7. I worked hard on the worksheet because I will someday need the knowledge in my job.
8. I tried to do as little as possible for the worksheet.
9. I am interested in exploring the topic covered in the worksheet further myself.
10. I will continue to think about the topic of the worksheet after school.
11. The worksheet does not play a major role in my everyday life.
12. I will talk to my parents about the contents of the worksheet.

The questionnaire, which also comprised a number of open-ended questions concerning the respondents' knowledge of ESD and their own relationship to sustainability, was completed by the students subsequent to the worksheets. The aforementioned items were evaluated using a four-point Likert scale (ranging from 'strongly disagree' (=1) to 'strongly agree' (=4)).

The data obtained in this way were analysed for differences between the different versions of a task using the Mann-Whitney U test. This test was chosen because we did not know whether the data collected were normally distributed.

3. Results

The following results focus on the comparison of the results of the rather positive and the rather negative versions.

The survey results of learners following completion of the respective worksheets are displayed in Figures 1 and 2. Figure 1 presents a comparison of the two versions of the 'Packaging' worksheet. Statement 5 ("I wish I hadn't had to do the worksheet".) demonstrates the most significant discrepancy between the questionnaire responses for both versions, with an average value of 0.61 points higher for the rather negatively formulated version compared to the rather positively formulated version. Accordingly, the learners

were less interested in not completing the worksheet in the rather positively formulated version of the worksheet.

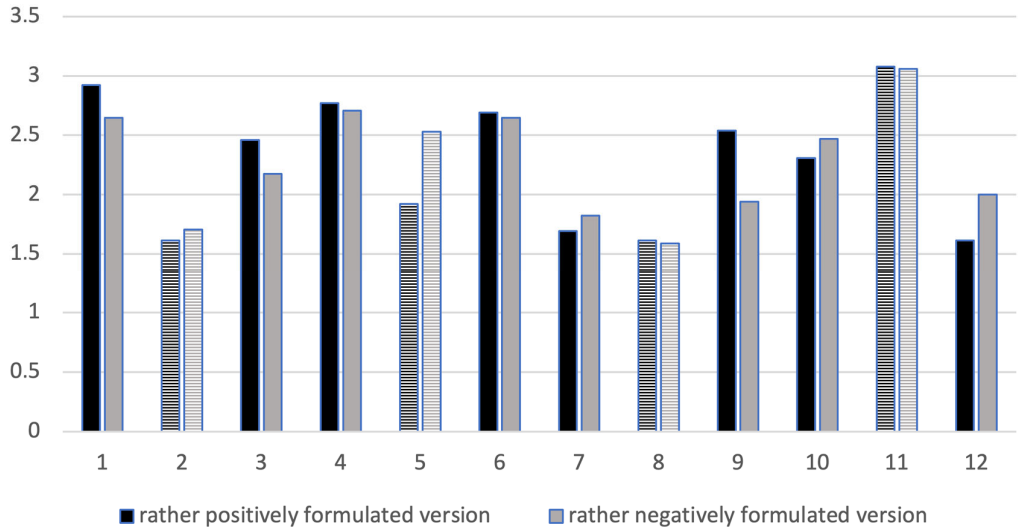

Figure 1. Item values for the two versions of the 'Packaging' worksheet (responses to items with negative wording are hatched).

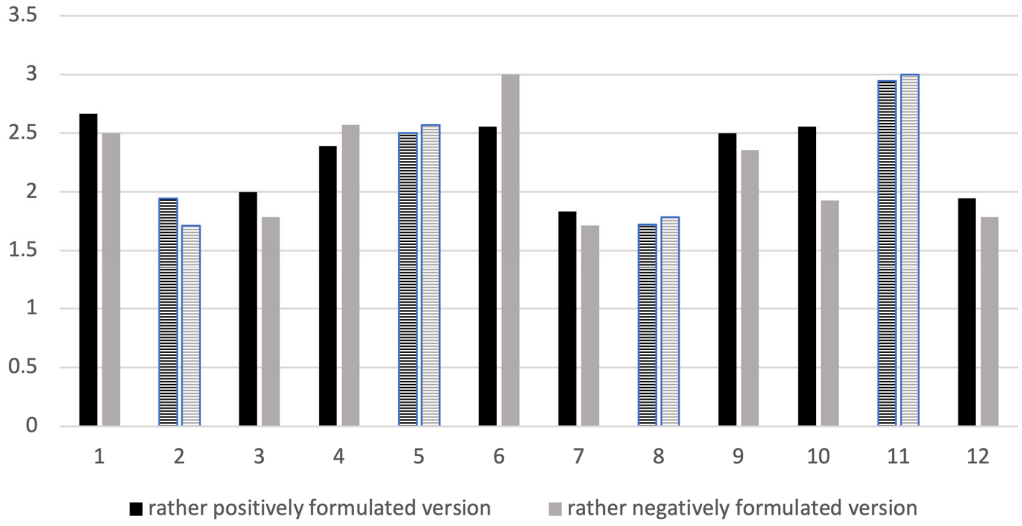

Figure 2. Item values for the two versions of the 'Rainforest' worksheet (responses to items with negative wording are hatched).

Statement 9, "I am interested in exploring the topic covered in the worksheet further myself", shows a comparable difference. The value of the positively worded version is 0.60 higher than that of the rather negatively formulated version. Accordingly, the learners in the rather positively formulated version of the worksheet appeared to be more interested in working on the topic themselves afterwards.

A Mann–Whitney U Test was subsequently calculated to test whether there is a difference between the two versions. For statement 5, a significant difference was determined, with a U = 66.00, Z = −2.00, p = 0.046, and an effect size of 0.37 (i.e., a medium effect size). For statement 9, the Mann–Whitney U Test demonstrated a significant difference U = 59.00, Z = −2.346, and p = 0.019, with an effect size of 0.43 (also a medium effect size). The two versions therefore differ statistically significantly in these statements.

Figure 2 presents a comparison of the different versions of the 'Rainforest' worksheet. In case of the 'Rainforest' worksheet, noticeable disparities can be observed in the responses

to statements 6 and 10. For statement 6 ("It was important to me to solve the worksheet, even if it had taken longer".), the mean value of the more negatively formulated version is 0.44 points higher than that of the more positively formulated version. Consequently, it can be posited that the learners exhibited a heightened inclination towards completing the worksheet that was formulated more negatively in terms of self-efficacy.

For item 10 ("I will continue to think about the topic of the worksheet after school"), the mean score for the positively worded version was 0.62 points higher than the mean score for the negatively worded version. Accordingly, the more positively worded worksheet may have had a more encouraging effect on the learners, potentially motivating them to engage in post-completion reflection.

The same statistical test was also conducted to quantify the differences in the responses to individual items. However, no statistically significant differences were found.

4. Discussion and Conclusions

The study examined the effect of different task formulations in mathematics education, whereby the tasks differed in terms of addressing self-efficacy. On the one hand, the tasks were framed positively, in the sense of achieving past successes, and negatively, in the sense of addressing still existing problematic situations. Neither the sample size, the number of tasks used, nor the number of statements used in the questionnaire permit vast generalisations, and the results of the study should be treated with caution due to the study's small scope. However, the results are relevant for future task design and, as we argued, can also be substantiated theoretically. They show that a divergent picture emerges: Concerning the questionnaire for worksheet 1, 'Packaging', a tendency for learners to favour the version formulated more positively in terms of self-efficacy could be observed. In contrast, the results for worksheet 2, 'Rainforest', show no clear preference.

We therefore asked ourselves how these values can be explained. In the course of our research, the issue of 'costs' arose in numerous discussions with teaching staff and researchers. It is evident that every action—and thus also the experience of self-efficacy in the context of sustainability—is accompanied by costs that people must be prepared to bear. The question therefore arises as to how much people (e.g., the learners from the study) are willing to do or give up to promote environmental goals. In sustainability contexts outside of mathematics education, it has already been investigated how various costs and willingness to make sacrifices affect the implementation of environmental measures and how these are linked to self-efficacy: The so-called low-cost hypothesis [31] states that the willingness to engage in environmentally friendly behaviour decreases with increasing perceived 'costs'. 'Low-cost' actions that require little sacrifice or effort (e.g., using fewer plastic bags) are easier to implement. A strong sense of self-efficacy is required for 'high-cost' actions that represent a more intensive lifestyle change (e.g., abstaining from air travel) [31].

The fact that self-efficacy is perceived because plastic packaging is already being avoided or reduced (task sheet 'Packaging') does not necessitate the explicit inclusion of own costs. Conversely, the transition to a vegan diet ('Rainforest' task sheet) has been shown to be a significant cost factor. The present results are consistent with the low-cost hypothesis insofar as they indicate that learners are more willing to engage with environmental goals if the expected actions are perceived as easy to implement and less of a burden. This suggests that tasks related to sustainability issues could be particularly successful if they are aimed at a sense of self-efficacy and, in particular, take into account the feasibility and suitability of sustainable actions for learners' everyday life.

Despite the speculative nature of this explanation, it aligns with the findings of previous studies [9], wherein a student articulated his or her aversion to ESD, stating, "I like eating meat and that's why it [ESD] doesn't interest me".

Regardless of their explanation, the findings indicate that even minor changes in the task in terms of addressing self-efficacy have the capacity to influence the interest and motivation of learners. This, in turn, supports Hoffmann's approach (see above), which focuses on the solution of a problem and the path to this solution rather than on the problems themselves.

Furthermore, the results demonstrate that the formulation and presentation of tasks play an essential role in the acceptance and interest of learners. In the process of creating teaching materials, particular attention can be directed towards initially focusing on actions that are realistic for learners and perhaps easier to implement. Teachers can promote self-efficacy through the careful selection of topics to be covered or small adjustments to task formulations, which in turn can increase learners' willingness to actively engage with topics of sustainability. Careful selection and handling of the sustainability context is an important prerequisite for dealing with ESD in the classroom.

In addition to increasing the number of students for the study, the study also provides several clues for further research: (1) In this study, we used motivation and interest as proxies for self-efficacy. We are currently researching a questionnaire that can directly assess self-efficacy in the context of sustainability for solving mathematical tasks [32]. (2) Two tasks were used in the study. Self-efficacy could also have been addressed in other ways. As the results of the 'Rainforest' task indicate, there appears to be a complex relationship between self-efficacy and interest/motivation, which can and should be analysed in more detail. (3) As the present study focuses on short-term effects, also outcomes of long-term effects could be observed.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data are contained within the article.

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Appendix A. The 'Packaging' Worksheet

Introduction

In the Pacific Ocean, far from any solid shore, there is a disturbing phenomenon that illustrates the impact of our global consumer society on the environment: the Pacific garbage patch (Figure A1). This gigantic vortex of plastic waste that covers an area more than three times the size of France (https://theoceancleanup.com/great-pacific-garbage-patch/ (accessed on 7 April 2025)).

Figure A1. Great pacific garbage patch (printing permission kindly granted: https://www.seasidestainability.org/post/the-great-pacific-garbage-patch-think-trash-soup-not-trash-island (accessed on 7 April 2025)).

This vortex has become a symbol of the challenges that plastic pollution poses to our oceans. This plastic pollution not only affects marine life but also impacts the human economy and environment. In a world that is heavily reliant on single-use plastic, a more sustainable shift in our mindset and in the way we produce and use plastics needs to be initiated.

In Germany alone, 6.3 million tons of plastic waste were generated in 2021. That's 76 kg per capita. The main component was packaging: calculated per capita about 38 kg per year (see www.nabu.de/umwelt-und-ressourcen/abfall-und-recycling/22033.html (accessed on 7 April 2025)).

In the rather "positive" version, now the following text appeared:

A lot has already happened in this respect in recent years. Many companies are trying to use alternative, plastic-free forms of packaging.

This includes one of the market-leading companies for margarine in Germany.

The group aims to use 95% plastic-free packaging by 2030 (www.chip.de/news/Darum-ist-Rama-gar-keine-Margarine-und-das-sagt-der-Hersteller-dazu_184476074.html (accessed on 7 April 2025)).

In the rather "negative" version, the text ("A lot has already happened . . . plastic-free packaging by 2030 (www. . . .)") was replaced with the following text (everything else remained identical): "Nevertheless, plastic packaging in supermarkets is the ubiquitous part of our everyday shopping. Whether it's vegetables, fruit, meat or basic household items, plastic packaging is often the rule, not the exception. Calls for more sustainable alternatives and a more conscious approach to plastic packaging are growing louder. Many consumers are actively looking for products with minimal or no packaging options which indicates a clear trend towards more environmentally conscious shopping behaviour. However, there are still numerous examples where there is a great need for action in terms of more sustainable packaging".

In 2022, the manufacturer reduced the filling quantity of one of its products. However, it did not change the packaging for cost reasons. In the following, we will now calculate how much plastic could be saved by optimizing the packaging shape and adapting it to the filling quantity.

The shape of the packaging can be described approximately as a cylinder (see Figure A2). The surface of the cylinder describes the packaging and therefore our amount of plastic. In the following tasks, the thickness of the packaging and necessary additions,

such as a mechanism for the lid, are neglected, as these are to be retained. Since we are neglecting the thickness, we are therefore specifying our plastic quantity in cm^2 as a model. The basic shape of the packaging should not be changed either. The filling quantity of the original packaging was 500 g and was reduced by 20% to 400 g.

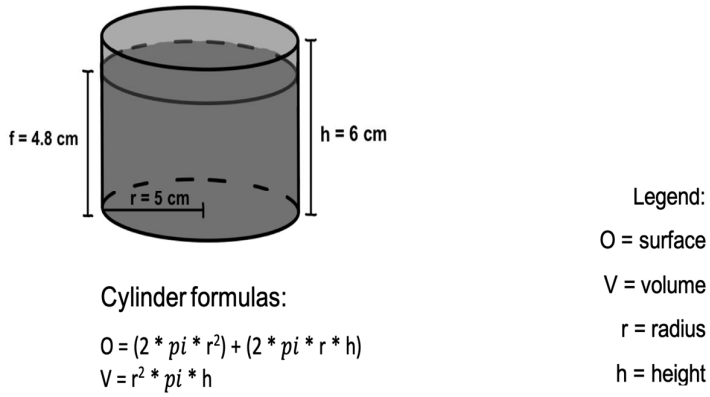

Figure A2. A cylinder and some formulas.

Task 1

Calculate the volume and surface area of the unchanged packaging. You will find the formulas next to the diagram.

Task 2

Determine how much plastic would be saved if the packaging was only as high as the filling line?

Task 3

Now calculate the radius and height of the cylinder that has the smallest surface area for the same volume.

Take the filling quantity into account. Since the reduced filling quantity also reduces the volume by an equivalent amount, a smaller package is now sufficient. How many cm^2 does the surface area decrease compared to the given packaging? How much plastic could be saved by optimizing each package?

Task 4

Can you find another geometric shape with an even more effective volume/surface area ratio?

Try out some common bodies.

If so, why might the manufacturer have decided against this form of packaging?

Task 5

Get together in teams of two and share ideas. Relate our newly acquired information to the initial situation and put it into context.

In 2022, 186,000 tons of margarine were consumed in Germany. Our manufacturer had a market share of 24 % in 2020. We assume that the market share and the amount consumed have not changed drastically.

Consider the following:

- Calculate the surface area that could be covered with the plastic saved each year.
- How should this problem be dealt with in Germany? Can you think of any solutions?
- What other deceptive packaging do you know, or can you think of after you have been familiarized with the term?

Sources:

https://theoceancleanup.com/great-pacific-garbage-patch/ (accessed on 7 April 2025)

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www.chip.de/news/Darum-ist-Rama-gar-keine-Margarine-und-das-sagt-der-Hersteller-dazu_184476074.html (accessed on 7 April 2025).

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https://de.statista.com/statistik/daten/studie/997384/umfrage/marktanteile-der-hersteller-von-margarine-und-brotaufstrichen-in-deutschland/ (accessed on 7 April 2025).

www.abendblatt.de/wirtschaft/article229180554/Rama-Margarine-Fett-Upfield-Unilever-Geschmack-Milchwirtschaft-Butter-Brotaufstrich.html (accessed on 7 April 2025).

Appendix B. The 'Rainforest' Worksheet

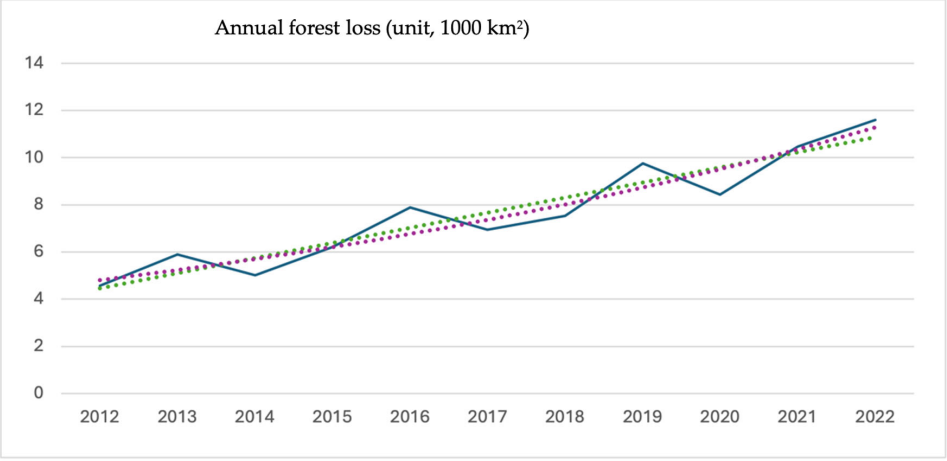
Introduction

The area of rainforest cleared each year is larger than half the area of Germany. This is also the case in the Amazon rainforest. Around 60% of the rainforest is located in Brazil.

The deforestation of the rainforest is a worrying reality that has far-reaching ecological consequences worldwide. As one of the most vibrant ecosystems on our planet, the rainforest plays a crucial role in regulating the global climate, biodiversity and the conservation of biological diversity. However, despite its undeniable importance, the rainforest is increasingly threatened by human activities, particularly large-scale deforestation. These destructive practices not only have a serious impact on native ecosystems but also contribute significantly to climate change.

Task part

In the last 10 years in particular, there has been a worrying increase in annual forest loss in Brazil (Figure A3).



The graph can be approximately described by the two functions:

$f(x) = 4.4164e^{0.825x}$ $(R^2 = 0.9018)$

$g(x) = 0.6407x + 3.8212$ $(R^2 = 0.8884)$

$x = 1$ describes the year 2012.

R² is the coefficient of determination: It describes how well the function matches the given data. It assumes values between 0 and 1. The closer it is to 1, the better the function represents the data.

Figure A3. Annual forest loss. (The purple and green graphs approximate the original data. The corresponding symbolic expressions are shown below the graphic. The solid line represents the annual forest loss. The graph was taken from the internet. From a mathematical perspective, the use of a continuous solid line is questionable, as only discrete data points for individual years are available. The data can be found here: https://en.wikipedia.org/wiki/Deforestation_of_the_Amazon_rainforest (accessed on 7 April 2025).

Task 1

Using the graphing calculator and the given functions, determine a forecast up to the year 2035.

Which of the forecasts given by the functions do you think is more realistic? Give reasons for your answers. Put your results into context.

The area that is cleared is mainly used for cattle breeding and the production of soy. For ethical reasons and because meat is a very resource-intensive food source, meat consumption has increasingly become the subject of debate. However, increasing trends in meat consumption can be observed worldwide. According to forecasts, the annual consumption of meat per capita will continue to rise worldwide until 2035.

The chart in Figure A4 shows the development of global meat consumption over the last 10 years.

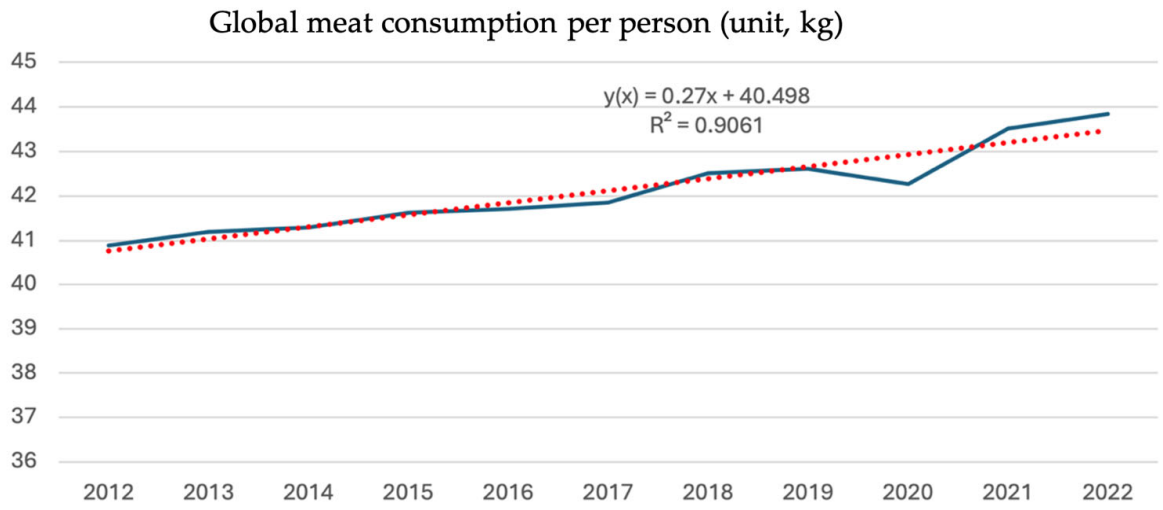
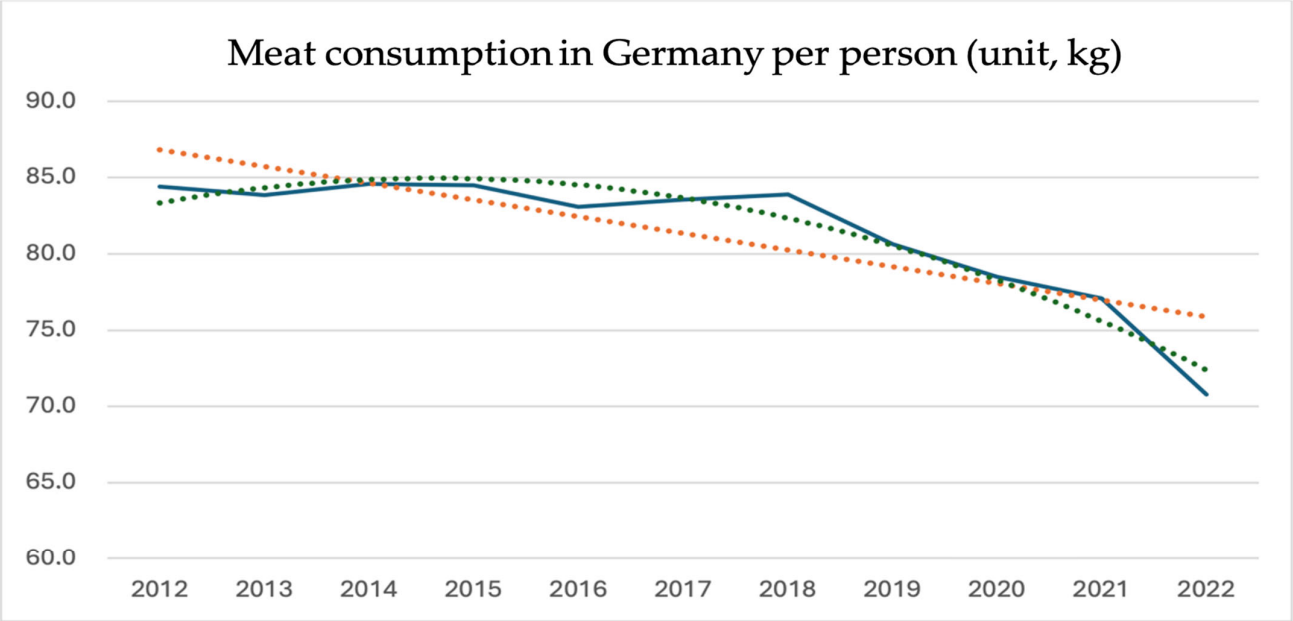


Figure A4. Global meat consumption (The red graph approximates the original data. The corresponding symbolic expression is shown in the graphic. The solid line represents annual global meat consumption per person in kilograms. The graph was taken from the internet. From a mathematical perspective, the use of a continuous solid line is questionable, as only discrete data points for individual years are available. The original data can be found here: https://ourworldindata.org/grapher/per-capita-meat-consumption-by-type-kilograms-per-year (accessed on 7 April 2025).

In the rather "positive" version, now the following text appeared: The trend in meat consumption in Germany has changed in recent years, indicating a growing awareness of sustainable nutrition and ethical consumption. A sharp decline in meat consumption can be observed. More and more people are consciously opting for a more balanced diet that also takes the ecological footprint into account. The increasing popularity of vegetarian and vegan alternatives is reflected in the wider availability and variety of plant-based products on the market.

In the rather "negative" version in terms of self-efficacy, the text (The trend in meat. . . products on the market) was replaced with the following (everything else remained identical): "In Germany, our meat consumption is well above the global average; in 2020, at 78 kg, we were around 85% higher (42 kg). Although a decrease in meat consumption can be observed, the average consumption remains worryingly high".

The chart in Figure A5 illustrates Germany's meat consumption.



Meat consumption in Germany can be modelled by the following two functions:

$j(x) = -1.0944x + 87.913$ $(R^2 = 0.698)$

$k(x) = -0.1254x^2 + 0.7414x + 84.96$ $(R^2 = 0.8825)$

Figure A5. Meat consumption in Germany (The orange and green graphs approximate the original data. The corresponding symbolic expressions are shown below the graphic. The solid line represents annual global meat consumption in Germany per person in kilograms. The graph was taken from the internet. From a mathematical perspective, the use of a continuous solid line is questionable, as only discrete data points for individual years are available. The original data can be found here: https://www.bmel-statistik.de/ernaehrung/versorgungsbilanzen/fleisch (accessed on 7 April 2025).

Task 3

Give arguments for the respective use of the functions for creating forecasts. Where do both functions reach their limits?

Task 4

Determine the year in which average German meat consumption per capita would fall below global consumption, assuming that both graphs develop in the same way? Use the function j(x) for German meat consumption.

Task 5 (The more negatively worded version of Task 5 was as follows: "Calculate how large the area of cleared rainforest would have been in 2022 if global meat consumption per capita had been as high as German meat consumption per capita. Determine how much rainforest was cleared per kg in 2022".)

In this task, we also use the function j(x) to describe the development of German meat consumption.

Determine and describe the effects on the clearing of the rainforest if global consumption were not to increase, as in the function y(x), but to fall, as German meat consumption is modelled by the function j(x).

Take into account the factor determined in Task 2.

Reference to the context

Get together in teams of two and exchange ideas. Record your thoughts in bullet points.

Also, address the following questions:

- What options can you think of to deal with this problem?
- How do you rate Germany in this context?

Sources:

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