Public Health 246 (2025) 105829

Contents lists available at ScienceDirect

Public Health

journal homepage: www.elsevier.com/locate/puhe

Original Research

Co-developing a planetary health module for pediatrics: a student-led initiative with peer teaching and evaluation of planetary health literacy

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ARTICLE INFO

Keywords:
Planetary health literacy
Planetary health education
Child health
Climate-sensitive health counselling
Planetary crises

ABSTRACT

Objectives: The aim of the study was to co-develop and implement a student-driven, interactive, and competence-based planetary health education (PHE) module on climate-sensitive health counselling (CSHC) in pediatrics and to evaluate pediatric planetary health literacy among medical students at a medical faculty in Germany.
Study design: This is a mixed methods study with a qualitative co-developing process of a teaching intervention in the pediatric curriculum of medical students and a pre-post evaluation. The questionnaires assessed whether the module could enhance students' planetary health literacy and evaluated its didactic design.
Methods: A teaching module titled "Child Health in Times of Planetary Crises" was co-developed, integrating insights from interviews with pediatricians practicing CSHC. Measurable learning objectives were created using Bloom's taxonomy. The module included an online course and a seminar that applied CSHC in pediatric scenarios, focussing on preventive and adaptive consultation. Pre- and post-course questionnaires assessed planetary health literacy, covering knowledge, understanding, and self-assessed competence, along with feedback on the course design. Statistical analysis included paired t-tests, Pearson correlations, and median comparisons.
Results: Students rated the module as "important", "interesting" and "neglected in the rest of the curriculum". Their planetary health literacy improved significantly across knowledge, comprehension of pediatrician's special responsibilities, and self-assessed competence to advise patients on adaptive and preventive measures ($p < 0.01$). The module's design received positive evaluation.
Conclusion: The module effectively enhanced planetary health literacy among medical students. Competence-based education on medical response strategies is essential for addressing children's vulnerability to growing health risks posed by planetary crises. We recommend integrating planetary health education into discipline-specific teaching and cross-disciplinary subjects.

1. Introduction

The first Planetary Health Check report shows that "Earth exceeds safe limits", threatening both human and planetary health.[1] For many years, climate change has been described as "the biggest global health threat of the 21st century".[2] Children and young people are particularly vulnerable to the health effects of the climate crisis, which is one aspect of the broader triple planetary crises that also include pollution and biodiversity loss.[3] Over 88 % of the global burden of disease caused by the climate crisis affects children under the age of five, both in the global South and the global North.[4] An increase of the average temperature by 1 °C causes 5 % more stillbirths, whereas higher temperatures are associated with lower birth weight.[5] Children are already experiencing the health risks of environmental change and will continue to face them throughout their lives, as "newborns in 2020 are projected to experience 2–13 times more extreme events during their life than a person born in 1960".[6]

Pediatricians, therefore, have a key role in educating their patients

This article is part of a special issue entitled: Health Literacy published in Public Health.

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https://doi.org/10.1016/j.puhe.2025.105829
Received 13 December 2024; Received in revised form 11 May 2025; Accepted 9 June 2025
Available online 28 June 2025

on how to best protect themselves from the health risks of planetary crises while also promoting sustainable development through healthy lifestyles choices.[7] In addition to providing adaptive health advice, health co-benefits play a crucial role in climate-sensitive health counselling (CSHC).[8] This involves encouraging behaviours such as active mobility or healthy, sustainable diets, which simultaneously support child health and contribute to preserving environmental resources. Despite the potential of CSHC in pediatrics, it is not widely reflected in the professional practice of pediatrics in Germany, with only about 10.5 % of 405 pediatricians reporting that they offer climate-sensitive health advice.[7] Internationally, "conversations about climate change and child health are neither part of standard pediatric practice nor occurring with the frequency demanded by the climate crisis".[9] An international survey found that 76 % of health professionals believe they need "continuing professional education on climate change and health",[10] and nearly 70 % expressed interest in "training to communicate effectively about climate change and health […] and patient education materials".[10]

Several planetary health education (PHE) frameworks have been established, such as the cross-cutting principles for PHE[11], the catalog of national Planetary Health learning objectives in Germany,[12] and the conceptual model on planetary health literacy.[13] These frameworks emphasize the importance of preparing "future physicians […] to acquire knowledge, values, skills, and leadership attributes to care for patients presenting with environmental change-related conditions".[12] However, there are still few projects that translate these recommendations into practical teaching. In most medical faculties in Germany, PHE is largely optional, occurring primarily through electives or student-led initiative.[12]

The aim of the current mixed methods study was to co-develop and implement a student-driven, interactive, and competence-based PHE module on CSHC in pediatrics, using a peer-teaching approach, and to evaluate pediatric planetary health literacy among medical students at a medical faculty in Germany.

2. Methods

2.1. Setting and time

During the summer semester of 2024 we conducted a mixed-methods study to assess and increase planetary health literacy among medical students at the University of Regensburg, Germany. The study consisted of two different parts: First, it started with a student-led qualitative co-design process with various methods to develop a teaching module about child health in times of planetary crises. Second, the module was embedded into a questionnaire-based pre/post evaluation with qualitative and quantitative parts testing the module's effects on planetary health literacy of the participating students and asking for feedback for the didactic design. All students who participated in the pediatrics exam in the tenth semester were invited to participate in the study. Participation was voluntary, and all participants provided informed consent for pseudonymous data collection.

2.2. Qualitative co-design of the module with an interdisciplinary team

The blended learning module was integrated into the pediatrics curriculum during the summer term of 2024. We employed various didactic methods to design the module, using the six-step approach to curriculum development[14] as a framework. This approach included identifying the need for a new module, considering the learning environment, defining specific and measurable learning objectives, aligning educational strategies with these objectives, implementing the module into the mandatory curriculum, and, finally, evaluating its effectiveness through a pre/post survey.

2.2.1. Qualitative expert interviews with pediatricians

To illustrate the need for teaching CSHC in pediatrics and to define realistic learning objectives, we conducted seven semi-structured guided interviews with pediatricians from clinical, outpatient, and scientific fields. We selected pediatricians who actively apply CSHC or are involved in its development process. The interview guide (supplementary material) was developed based on the recommendations of Niebert et al.[15] It includes questions on the impact of the climate crisis on children's health as observed in their clinical practice, the unique responsibility of pediatricians to take transformative actions, and the current need and status of CSHC. The guide also explores best-practice examples of CSHC in pediatrics across different counselling situations, as well as the responses from patients, encountered barriers, and political or structural requirements for effective implementation. Additionally, the pediatricians were asked to identify key learning objectives and skills they consider essential for medical students regarding planetary crises and child health. The interviews lasted between 30 and 60 min and were analysed using the qualitative framework method,[16] assisted by the software MAXQDA (Release 24.5.1). Insights from these expert interviews informed the design of the application-orientated exercises for students and the selection of learning objectives for the module. The role plays used in the seminar to practice CSHC in various counselling scenarios were developed based on the findings from the expert interviews. The topics were selected because pediatricians identified them as particularly relevant to their current clinical practice. Moreover, the diversity of the scenarios was intended to reflect the spectrum of CSHC, ranging from adaptive to preventive approaches, and to demonstrate how it can be effectively integrated into routine pediatric counselling. Detailed instructions for the role plays are provided in the supplementary material and are available for use in similar educational contexts. Interdisciplinary ABC Workshop with medical students, researchers and practitioners.

2.2.2. Interdisciplinary ABC Workshop with medical students, researchers and practitioners

A workshop, based on the ABC Learning design from University College London,[17] was conducted as part of the module design process. This 90-min workshop brought together an interdisciplinary team, led by a medical student, to co-develop the module's core objective and learning dimensions according to Laurillard's[18] framework. The team discussed the distribution of blended-learning methods, selected appropriate teaching strategies, and considered feedback mechanisms for students.

2.2.3. Formulation of learning objectives based on Bloom taxonomy

The learning objectives were defined using Bloom's[19] taxonomy, ensuring they were specific and measurable. They were categorized into the levels of *remembering, understanding,* and *applying,* which form the base of the hierarchical pyramid of six learning dimensions (Table 1). These learning objectives were further mapped onto the conceptual model of planetary health literacy (Table 2),[13] which was used to classify the objectives for fostering transformative skills. planetary health literacy is defined as "the knowledge and competencies of accessing, understanding, appraising, and applying information in order to make judgements and to take decisions regarding planetary health across societies and for health-promoting, sustainable, and transformative actions".[20]

2.3. Pre-post evaluation

2.3.1. Study instrument

We designed two questionnaires for pre/post-evaluation in German (English translation available in supplementary material). These were completed before the module and directly after the second part (Fig. 1). Participation was voluntary and anonymous. To link the responses from both questionnaires, we used a pseudonymous, individual code. The surveys were developed by the authors. The pre-evaluation questionnaire consists of three questions asking for demographic characteristics

and eight statements, which students rated on a five-point-Likert scale, where 1 indicated "I don't agree" and 5 indicated "I totally agree". In the post-evaluation questionnaire, the 11 statements of the pre-survey are repeated. In addition, there are seven statements on the same five-point-Likert scale and three general free-text questions regarding the learning experience of the module.

2.3.2. Quantitative data collection and analysis

The data were transferred to Microsoft Excel software (Version 2402) for data cleaning. We used the program R (Version 4.4.0) for statistical analysis. The normal distribution of the data was tested using Q-Q-Plots. We calculated mean differences with standard deviations and the percentage change of the planetary health literacy - categories, using paired t-tests with a significance level of $p < 0.01$. Furthermore, we calculated exploratory Pearson correlation coefficients between various statements in the post-evaluation, with significance also tested at $p < 0.01$. To evaluate the results of the post-evaluation survey concerning the module's didactics, we calculated the mean values of the Likert-scale items along with their standard deviations.

2.3.3. Analysis of free-text answers in the post-evaluation

In the post-survey, students were asked to complete three open-ended prompts: "When my fellow students ask me about the module, I say …", "I liked that a lot …" and "That's what I was missing …". The free-text responses were analysed using a summarising qualitative analysis method[21] and categorized to accurately capture the student's opinions. Answers were translated into English, and similar answers were grouped into appropriate categories and counted. The categories were then visualized in three word clouds, one for each question, using MAXQDA. The size of each category title in the word clouds corresponds to its frequency in the analysis. All steps were carried out by one author and supervised by another.

3. Results

3.1. Interdisciplinary co-development of the module

3.1.1. Developed learning objectives mapped on framework for Planetary Health Literacy

3.1.2. Blended-learning: online course with the basics on planetary crises and in-person seminar with exercises on climate-sensitive health counselling

The blended-learning module is part of the pediatrics curriculum in the final semester of the clinical section. Its structure is shown in Fig. 1.

3.2. Pre-post evaluation

A total of 74 medical students took part in the whole pediatric module. Of these, 67 completed both the pre- and post-questionnaires, and their responses were included in the final analysis, resulting in a

Table 1
Learning objectives, developed and categorized with the taxonomy of Bloom[19]

At the end of the module, the students will be able to	
- name the main health effects of the three planetary crises on the patient group of children and adolescents. - describe the principle of CSHC.	*remembering*
- explain why children and adolescents are among the vulnerable groups in the three planetary crises. - explain the special responsibility of pediatricians regarding CSHC in pediatrics.	*understanding*
- apply the principles of CSHC in pediatrics exemplarily in one of the fields of nutrition, mobility, travel counselling, infectiology, heat, allergology in a patient consultation.	*applying*

Abbreviations: CSHC = climate-sensitive health counselling.

Table 2
Learning objectives adapted to the conceptual model of planetary health literacy.[13]

	Access / obtain information regarding planetary health	Understand information regarding planetary health	Appraise / judge information regarding planetary health	Apply / use information relevant to planetary health
Overarching contents regarding planetary health literacy	Ability to access information on the interconnectedness of human health, the state of the natural systems, and human activities for planetary health.	Ability to understand information on the interconnectedness between human health, human activities, and the state of the natural systems.	Ability to interpret and evaluate information on the diverse relationships between human activities, human health, and the state of the natural systems.	Ability to make informed decisions regarding human activities or human health in the context of the state of the natural systems.
Module "child health in times of planetary crises"	*At the end of the module the students will be able to* - *access information on the main health effects of the three planetary crises on the patient group of children and adolescents.* - *access information on the principle of climate-sensitive health counselling (CSHC).* - *access information on possible consultation topics. for pediatric CSHC, especially the fields of nutrition, mobility, travel counselling, infectiology, heat, mental health and allergology.*	*At the end of the module the students will be able to* - *understand information regarding the vulnerability of children and adolescents in the three planetary crises.* - *understand information regarding the special responsibility of pediatricians within the health care system concerning the application of CSHC.*	*At the end of the module the students will be able to* - *appraise the information relevant for CSHC in the fields of nutrition, mobility, travel counselling, infectiology, heat, mental health and allergology in a patient consultation, and to appraise the feasibility of CSHC with respect to the chances and limitations.*	*At the end of the module the students will be able to* - *draw informed decisions on the appropriate situation in pediatric care for the implementation of CSHC and to draw informed decisions on the content and context for CSHC.*

Abbreviations: CSHC = climate-sensitive health-co benefits.

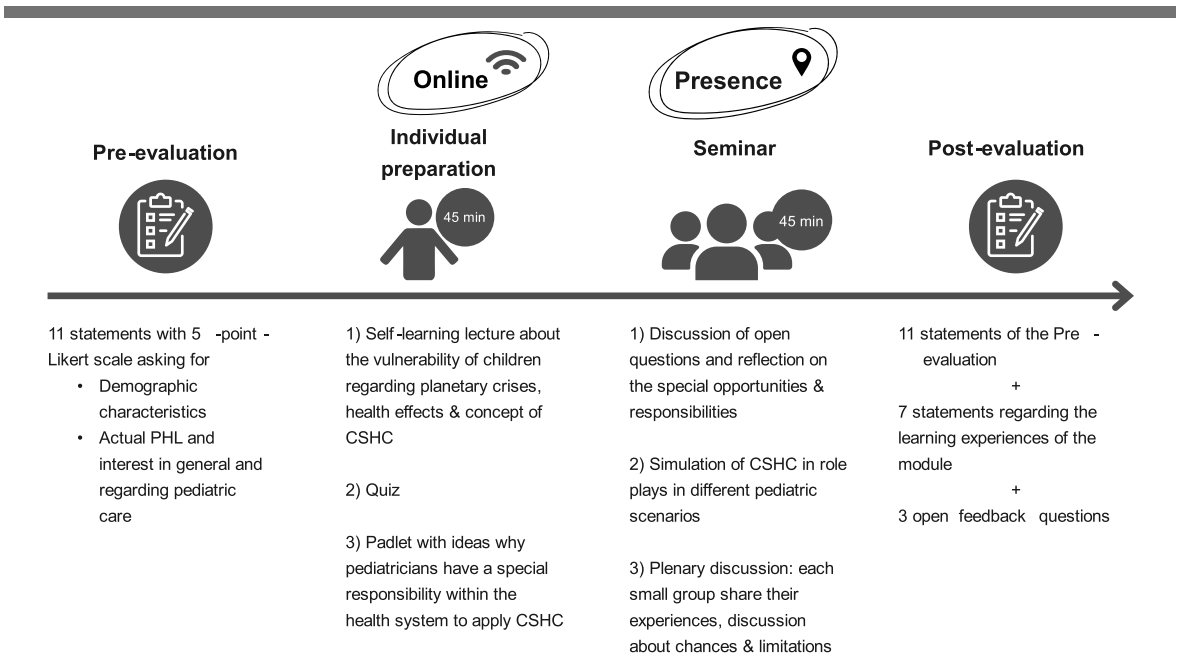

Fig. 1. Structure and didactic methods of the blended-learning module and the pre-post-evaluation; Abbreviations: CSHC = climate-sensitive health counselling, PHL = planetary health literacy; In the online course the students create the basis with an online course concerning the first four learning objectives at the level of remembering and understanding in order to then translate their knowledge into application in the seminar. Exercising the role plays the students should learn how to assess the needs and attitudes of patients and then provide CSHC implicitly or explicitly on the various topics. These vary greatly with regard to the focus on mitigation or adaptation of the health to planetary crises and thus cover a broad spectrum of paediatric tasks.

response rate of 90.54 %. Overall, seven students were excluded because they only completed the post-evaluation. Among the 67 students included in the study, 65.67 % (n = 44) were female and 34.33 % (n = 23) male. All participants were in their tenth semester of medical studies, with an average age of 25.54 years.

3.2.1. Quantitative analysis. On average, students rated each of the seven statements about the seminar design in the post-evaluation questionnaire around "I rather agree", with minimal variation in the means. The highest-rated aspect was the variety of methods used in the seminar design (mean = 4.40), followed by the online materials supporting the learning process (mean = 4.12). The lowest-rated aspect was the feedback from fellow students (mean = 3.96). Table A in the supplementary material provides the mean evaluation and standard deviation for each statement.

Data from the pre-post-evaluation were matched for 67 participants. Table 3 shows the mean changes across ten categories of self-assessed planetary health literacy among participating students as a result of the module.

An increase in planetary health literacy was observed across all evaluated categories after the module. The largest change was in knowledge of materials, with an increase of 110.89 %, followed by knowledge of the concept of CSHC (83.33 %). The smallest change was in student's interest in the connection between pediatrics and planetary health, with an increase of 2.71 %. Six out of ten categories showed a statistically significant increase at the $p < 0.01$ level, while another category reached significance at the $p < 0.05$ level. The understanding of pediatricians' special responsibility regarding CSHC was already relatively high in the pre-evaluation. The change in interest was not significant in any of the three related rubrics.

Pearson correlations between selected items in the post-evaluation questionnaire were calculated to explore potential relations between different dimensions of planetary health literacy. Given that the learning objectives target distinct hierarchical levels of learning, it was considered meaningful to assess whether the didactic concept was effective. For instance, we aimed to examine whether students with higher levels of knowledge also reported greater self-assessed competence in applying CSHC. The highest Pearson correlation ($r = 0.74$, $p < 0.01$) was observed between students' interest in planetary health and their interest in the connection between planetary health and pediatrics. There was also a strong correlation between knowledge about the health effects of planetary crises and the principle of CSHC, and students' self-assessed competence to apply CSHC in adaptive and preventive consultations ($r = 0.56$ to 0.59). Table B in the supplementary material provides additional details on various correlations.

*3.2.2. **Qualitative analysis of the free-text answers in the post-evaluation.*** A total of 46 students (68.7 %) responded to the open-ended question in the post-evaluation, in which participants were asked what they would tell their fellow students about the module. The three most frequently mentioned themes were "interesting", "neglected in the rest of the curriculum" and "important topic" (Fig. 2). The second question, regarding what participants liked about the module, was answered by 45 students (67.2 %), with the most-described codes being "lecture", "currency and relevance", and "online module" (Fig. 2). The third question, asking what participants felt was missing from the module, was answered by 13 students (19.4 %). The most frequently mentioned aspects were "more concrete tips for action" and "more time" (supplementary material).

4. Discussion

The aim of this mixed methods study was to co-develop a planetary health module for pediatrics within an interdisciplinary team, initiated by a medical student, to integrate various PHE frameworks into teaching practice. Recently, eight new Planetary Health Learning Objectives were developed for global health education to help educators focus on key topics within the field of planetary health.[22] However, both nationally and internationally, specific learning objectives that address the intersection of children's health and planetary crises remain scarce and often

Table 3
Mean changes in planetary health literacy with the focus in pediatrics.

Learning objective	Mean (SD) Pre	Mean (SD) Post	MD (SD) Pre-Post	MD (%) Pre-Post
Knowledge regarding health effects of planetary crises	2.78 (1.11)	4.06 (0.92)	1.27[a] (1.41)	45.45
Knowledge regarding concept of CSHC	2.32 (1.15)	4.27 (0.91)	1.94[a] (1.36)	83.33
Comprehension of children's vulnerability regarding planetary crises	2.69 (1.06)	4.13 (0.89)	1.45[a](1.22)	53.88
Comprehension special responsibility pediatricians to respond to the health effects of the planetary crises	3.85 (0.96)	4.01 (1.01)	0.16** (0.98)	4.26
Self-assessed competence to advise on adaptation measures	1.88 (0.91)	3.31 (0.96)	1.43[a] (1.00)	76.19
Self-assessed competence to advise on preventive and mitigative measures	2.87 (1.07)	3.45 (1.00)	0.58[a] (1.21)	20.31
Knowledge regarding existing material, literature for further education	1.51 (0.79)	3.18 (1.07)	1.67[a] (1.24)	110.89
Interest in pediatrics	3.06 (1.35)	3.16 (1.33)	0.10 (0.70)	3.41
Interest in planetary health	3.37 (1.13)	3.52 (1.13)	0.15 (0.76)	4.42
Interest in the connection between pediatrics & planetary health	3.20 (1.17)	3.28 (1.26)	0.08 (0.81)	2.71

[a] Statistically significant with the significance level $p < 0.01$, **$p < 0.05$; Abbreviations: CSHC = climate-sensitive health counselling, MD = mean difference, SD = standard deviation.

focus narrowly on the impacts of climate change on children as a vulnerable population.[23] Our module addresses this gap by translating general PHE recommendations into concrete, discipline-specific learning objectives for pediatrics, with a particular emphasis on transformative action. Based on our findings, we recommend embedding PHE not only in subject-specific teaching but also in cross-disciplinary subjects, as well as in teaching broader skills such as medical consultations.

The module aimed to increase the planetary health literacy of participating students, focussing on applying CSHC, which was assessed trough a pre-post evaluation. The main results show that students' planetary health literacy increased significantly in the categories of knowledge, comprehension, and especially in self-assessed competence to apply CSHC. This finding highlights the transformative purpose of the module. The didactic design of the module was rated highly by the students, with each statement averaging "I rather agree", indicating that the methodical variety, constructive alignment, feedback format, and provided materials were well-received. A key finding was the increase in students' planetary health literacy after the module, with the largest gains in knowledge and self-assessed competence to apply CSHC. The substantial improvement in knowledge of the principles of CSHC, existing literature, and the health effects of planetary crises may be attributed to the general lack of PHE in standard medical curricula. The increase in self-assessed competence to apply CSHC might be explained by the theoretical introduction of CSHC and practical exercises during the seminar, where students applied CSHC in various pediatric consultation scenarios and discussed clinical feasibility, opportunities, and limitations. This is further supported by the positive correlation between knowledge and self-assessed competence, where students with a higher level of knowledge felt more capable of applying CSHC. It is noteworthy that self-assessed competence to apply adaptive CSHC was lower than for preventive CSHC. However, post-evaluation values in both competence categories were similar, suggesting that the module successfully conveyed strategies for both adaptive and preventive consultations.

Students' initial interest in pediatrics, planetary health, and their intersection was moderate before the module and did not increase significantly afterward, contrasting with the positive feedback in open-ended questions, where the module was described as an "important topic", "interesting", and "relevant", consistent with the results of a similar project.[23] Students also expressed a desire for more time to practice and for more concrete action tips. Time for practice is important to deepen knowledge and skills related to CSHC, but as an extracurricular topic, it is challenging to allocate additional time within the required pediatrics curriculum. As pediatricians often cite the lack of PHE as a barrier to applying CSHC, there is a need to integrate this topic into general curriculum for medical education to support implementation by educators. In Germany for example, progress is being made to include PHE in the competency-based national curriculum, with a supplementary catalogue already addressing Planetary Health Learning Objectives.[12] Our module aligns well with these objectives, targeting knowledge, values and attitudes, and leadership skills.

Our study has several limitations. First, we could only assess the short-term impact of the module, as students' planetary health literacy before and directly after the module, with a time interval of two to eight weeks. Long-term impacts would be valuable to investigate. Second, the self-assessment of planetary health literacy may introduce reporting bias. Furthermore, the results do not provide in-depth insights into specific planetary health literacy aspects, such as which consultation scenarios require more background information to apply CSHC. In addition, while the design process was time-intensive, making it challenging to replicate for every new PHE-related topic in the medical curriculum, pilot studies like ours are valuable for identifying effective didactic approaches for PHE.

Nevertheless, our study has several strengths. First, the mixed methods design of the study with a qualitative co-development of the teaching module and a pre-post-evaluation of the designed module and its impact on the students'PHL helps to carefully test the achievement of the targeted learning objectives. Second, unlike many additional or elective planetary health courses, which attract mainly self-selecting

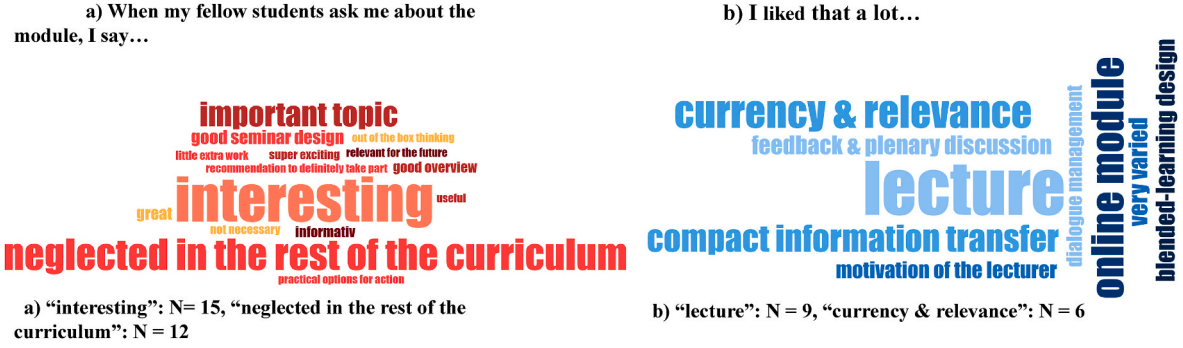

Fig. 2. Word clouds for the answers for the open questions in the post-evaluation; the size of codes shows the number of similar answers.

students, our module is part of the mandatory curriculum, minimizing the risk of selection bias. We recommend integrating PHE into the core curriculum for all medical students to ensure broad planetary health literacy competence. Third, the study encourages the sharing of data and teaching materials. The module's simple structure and manageable materials make it easy to adopt in curricula of other universities, both nationally and internationally. The topic is globally relevant, and the module emphasizes climate (in)justice by highlighting how marginalized groups, particularly in the global South, are more affected by planetary crises. We actively engage with medical faculties in Germany, encouraging them to replicate the module and offering training in pediatric CSHC for assistant physicians. Forth, the learning objectives are based on insights from expert interviews, providing a practical perspective on CSHC in pediatric consultations. The role-playing activities in our module closely mirror real clinical situations, addressing both therapeutic and preventive responses to planetary crises and emphasizing health co-benefits.[23] Finally, the student-led nature of the study is a unique strength. This initiative – encompassing study planning, co-development of learning objectives, module design, peer teaching, and student-driven evaluation – demonstrates the importance of equipping the next generation of health professionals with transformative planetary health literacy skills. The international Planetary Health Report Card is a similar example, where students have driven a survey of PHE across medical schools worldwide.[24] In our study, the lectures and seminars were delivered by a student, following the peer-teaching model in PHE, where students "bring fresh ideas and possibly greater knowledge of the climate and ecological crisis".[25] This student-led approach and peer-teaching foster a collaborative learning environment, allowing students and educators to "co-create the necessary new learning",[25] making PHE less hierarchical and enabling students to deepen their own planetary health literacy through research, networking, and teaching.

In conclusion, our study demonstrated a well-received co-development process of a competency-based, student-led planetary health module. Student-led development has been crucial for implementing PHE in various medical faculties and should be institutionalized. Future doctors require adequate training to strengthen their planetary health literacy and improve their practical skills in CSHC. Pediatricians play a decisive role in transformative change by protecting a vulnerable patient group and promoting health-co benefits. This study suggests, that co-development of mandatory modules on child health in the context of planetary crises can provide medical students with the knowledge, understanding and skills to provide planetary health care.

Author statements

Ethical approval

An ethical approval was not necessary.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Competing interests

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Data sharing

Requests to access the deidentified datasets can be directed to the corresponding author up to five years after article publication.

Author contributions

SB, CJ contributed to the idea, concept, and coordination of the project. SK and SH coordinated the implementation of the module in the pediatric curriculum. SB, CJ, LP, SK, and SH participated in the ABC-workshop. SB, CJ, and LP developed the specific learning objectives. SB designed the lecture, the online course, and the seminar with the support from CJ. SB, CJ, LP contributed to the development and implementation of the questionnaires. SB and CJ verified the data set. All authors had access to the study data. SB and CJ guided the data analysis. The quantitative analysis was carried out by SB with support from CJ, the qualitative analysis was carried out by SB and CJ. SB and LP created the figures and tables with support from CJ. ML engaged in critically reviewing the manuscript. All authors were involved in the writing and review of the draft.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2025.105829.

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