BMC Public Health

STUDY PROTOCOL

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Enhancing iodine health awareness among adolescents: a study protocol for a multi-country intervention study in educational settings across the UK, Slovenia, Cyprus, Bangladesh, Germany and Pakistan

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Abstract

Background Mild-to-moderate iodine deficiency remains a public health challenge, particularly in Europe and in areas where access to iodine-rich foods or iodised salt is limited. Adolescents are a key target group for interventions, as early awareness can reduce the risk of iodine deficiency during future pregnancies. The EUthyroid2 project aims to raise iodine awareness among adolescents (aged 13–17y) to improve their iodine awareness and possibly iodine intake and indirectly enhance the health of them and their future children.

Methods A multi-country intervention study will be conducted in educational settings across six countries (Bangladesh, Pakistan, Slovenia, Cyprus, Germany and the UK). Data on iodine awareness, dietary habits, and socioeconomic status will be collected at baseline (T1), 2–4 weeks post-intervention (T2), and 26–34 weeks post-intervention (T3). A convergent parallel mixed-methods design will be employed for process evaluation. The intervention includes three components: teaching modules, an iodine feedback tool, and an online learning platform. The core content includes an iodine feedback tool and a lecture on iodine-related knowledge and awareness, accompanied by student exercises. A total of 4,500 students will be recruited.

Discussion The main outcome of the study is the change in participants' awareness and knowledge of iodine from baseline (T1) to follow-up points (T2 and T3). The intervention is expected to effectively improved understanding of iodine's importance for health and promoted positive behavioural intentions related to iodine intake, while also providing an opportunity to enhance iodine nutrition beyond the scope of the current trial. This study contributes

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to evidence on effective health promotion approaches aimed at addressing iodine deficiency. Expanding such awareness interventions could lead to lasting improvements in public health by reducing the prevalence of iodine deficiency disorders, particularly among adolescents and future generations.

Trial registration ClinicalTrials.gov number NCT06769009. Registered 2025-01-08.

Keywords Iodine awareness, Adolescent health, Health education intervention, Multi-country study, Iodine deficiency, Public health promotion

Background

Improving iodine awareness is crucial for preventing iodine deficiency disorders (IDD) and ensuring optimal health outcomes for future generations [1]. Iodine insufficiency remains a significant public health concern in many countries worldwide, particularly affecting young women of reproductive age [2, 3]. By educating adolescents about the importance of iodine in their diet, we can establish a foundation of knowledge and awareness that will benefit them throughout their lives, especially when they consider becoming parents.

Iodine is a micronutrient essential for the production of thyroid hormones, which are vital for metabolism, growth, and cognitive development [4, 5]. Insufficient iodine intake can lead to a range of health issues, including impaired thyroid function, goitre, and cognitive impairment [6]. The World Health Organisation (WHO) recommends a daily iodine intake of 150 micrograms for adults, with an increased requirement of 250 µg during pregnancy or lactation [7].

Iodine intake among adolescents varies significantly across different regions. In Europe, despite general sufficiency, some countries still report mild to moderate iodine deficiency among adolescents [1]. By contrast, our Asian partner in the Euthyroid2 consortium: Bangladesh; has made progress in combating iodine deficiency, but many adolescents, especially in rural areas, still have insufficient intake [8, 9]. Similarly, in Pakistan, a considerable proportion of adolescents remain iodine deficient [10]. The iodine deficiency pattern in pregnant women of Cyprus is concerning, as inadequate iodine intake during pregnancy would adversely affect foetal brain development [11]. The lack of mandatory salt iodization policies and limited public awareness contribute to this issue. Additionally, shifts in dietary habits, such as reduced consumption of iodine-rich foods like dairy and fish, may exacerbate the problem. Overall, the primary dietary sources of iodine include iodised salt, seafood, milk and dairy products, and eggs [1]. Increasing awareness about iodine nutrition during adolescence is crucial, especially for young women, as adequate iodine status before conception is essential for optimal foetal development [12, 13]. Improved awareness thus prevents potential health issues related to iodine deficiency in future pregnancies. Consequently, most studies concerning iodine deficiency and its related health issues have primarily focused on young women [14, 15]. However, few studies investigate outcomes, such as health or cognitive effects, among school-aged children and adolescents. Most existing studies investigate iodine status [16, 17], with only a few intervention studies looking into how iodine deficiency can be prevented. Furthermore, most of these interventions have been conducted in resource-poor communities with moderate-to-severe iodine deficiency [18, 19]. The current state of research highlights a significant gap in our understanding of iodine awareness and intervention effectiveness among school-aged populations in diverse socioeconomic settings.

Adolescence is an important period for establishing healthy dietary habits and nutritional awareness [20]. By targeting this age group, we can establish early awareness, as educating adolescents about iodine's importance creates a foundation of knowledge that can persist into adulthood [21]. Improving iodine awareness among adolescents is a proactive approach to preventing IDDs, equipping young people with the knowledge needed to make healthy choices throughout their lives, particularly when they consider starting a family [22]. While both sexes benefit from increased knowledge and awareness of iodine, it is particularly crucial for young women who may become pregnant in the future. Further, schools and other educational institutions provide an ideal platform for promoting nutrition information and healthy habits as schools reach across socio-demographic groups. By implementing iodine education programmes in schools, we can ensure that adolescents, regardless of their socioeconomic background, receive essential information about iodine nutrition. This can lead to long-term improvements in iodine awareness and knowledge and further the prevention of iodine deficiency. A systematic review from 2020 by Shapu et al. found that school-based nutrition education programmes can effectively improve students' nutrition knowledge and dietary behaviours, including micronutrient intake [23].

Prevention among adolescents as a proactive approach

The EUthyroid consortium has highlighted the lack of awareness about iodine nutrition as a significant barrier to addressing iodine deficiency in European and non-European countries [24]. By implementing

comprehensive iodine education programmes in schools and other educational institutions, we can create a generation of informed individuals who understand the importance of adequate iodine intake and prevent IDDs. This strategy aligns with global efforts to reduce the prevalence of iodine deficiency and its associated health risks [13].

Therefore, this study aims to investigate the impact of an intervention designed to increase knowledge and awareness of iodine and IDDs among adolescents (13–17 years) in educational settings. The intervention is multimodal and conducted in six study regions: Cyprus, UK (Northern Ireland and England), Slovenia, Germany, Bangladesh and Pakistan. Secondary schools, high schools and vocational schools will be included to represent various types of educational institutions within each study region, although the specific types of schools included may differ by region. In addition to the educational component, the EUthyroid2 project includes a parallel intervention in ambulatory care settings focusing on young women; both components aim to improve knowledge, awareness, and iodine-related practices. The ambulatory care intervention is implemented in Poland, Norway, UK (Northern Ireland and England), Bangladesh and Pakistan.

Main research questions

The primary outcome of this study is to assess the effectiveness of an educational intervention in increasing iodine awareness, which results in the following primary research question:

- Does the educational intervention on iodine in the selected educational settings increase iodine awareness in 13-17-year-old students?

To effectively target future nutrition education and awareness programmes, it is essential to determine the age groups that respond most favourably to specific approaches and teaching methods. Considering this objective, the study will further assess differences between teaching modalities, educational settings, age groups and gender and assess behaviour change through the following research questions:

1. Are some teaching modalities more effective than others in increasing iodine awareness?
2. Do specific teaching modalities affect the retention of increased iodine awareness among students, as measured between the first follow-up (2–4 weeks) and the second follow-up (6–8 months) after the intervention?
3. Does the educational setting (comparing vocational schools, high schools and secondary schools) influence the potential increase in iodine awareness among students?
4. Are there differences in outcomes regarding iodine awareness among students when considering various age groups and gender distinctions?
5. Does increased iodine awareness lead to healthy behaviour change and healthier iodine intake habits?

Methods and analysis

This study protocol describes a multi-country pre-post educational intervention study on iodine without randomisation; the intervention is: "The ABC of Iodine" teaching programme. The study design is outlined in Fig. 1. The educational intervention is based on a flexible model that can be adjusted to suit the regional contexts within the specific region. This is essential because there are significant cultural and contextual variations among the study regions, requiring adaptations to effectively address the diverse circumstances [25].

Study setting

The study is conducted in six regional implementation sites, selected because they also participated in the previous EUthyroid1 study: Cyprus, the UK (Northern Ireland and England), Slovenia, Germany, Bangladesh and Pakistan. Germany was not originally designated as a study region; however, practical and organisational considerations led to the inclusion of Germany in the study shortly before the recruitment phase started. Germany's inclusion is also justified by comparable iodine status data with other European study regions.

Expected timeline

The first students are enrolled at the beginning of 2025. The enrolment is expected to be finalized in 2025, and thus the last follow-up will be conducted in the summer of 2026.

Participants and recruitment

Students (aged 13–17) are recruited in secondary schools, high schools, and vocational schools in The Republique of Cyprus, Slovenia, the UK, Germany, Bangladesh, and Pakistan. Intervention schools are recruited by a participant management unit that manages personal data in compliance with GDPR. Schools are initially contacted in writing, providing them with comprehensive study information. This is followed by phone calls or personal visits to ensure they fully understand the study's purpose and procedures and to address any questions or concerns they may have. This approach helps to build trust and encourage participation in the study. If interest is expressed, information meetings are held to present the study to teachers, students, and parents.

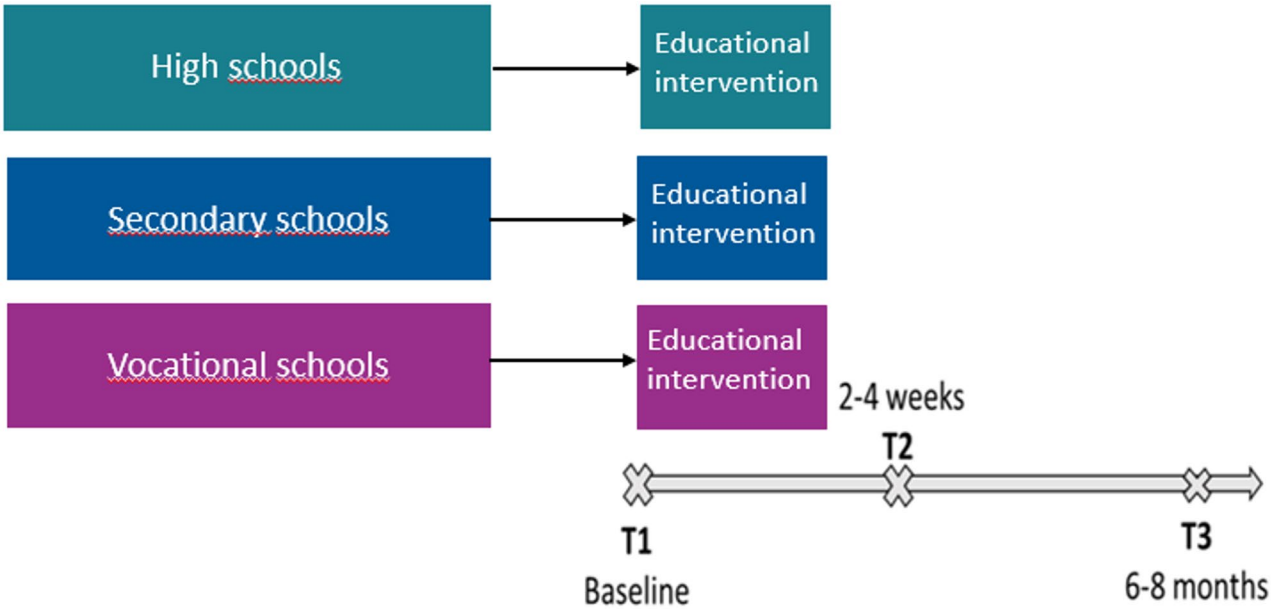

Fig. 1 Study design of the pre-post educational intervention study. Students in enrolled schools complete measurements at three time points: T1 - at baseline (before receiving the intervention), T2 - after 2–4 weeks and T3 - after 6–8 months. All recruited students receive the intervention. The specific types of schools included may differ by region

Table 1 Overview of implementation sites and school types in the study regions

Region	Implementation sites	School type (vocational, high or secondary)
Republic of Cyprus	19 schools across the regions of Nicosia, Limassol, Larnaka and Eleftheri Ammoxwstos	Secondary
Northern Ireland	Country-wide	Secondary
England	London and the South-East	Secondary
Slovenia	Country-wide	Primary schools, high schools, vocational schools
Germany	Federal State Mecklenburg-Vorpommern	Secondary
Bangladesh	Mirpur area of Dhaka north	Secondary, higher secondary and vocational
Pakistan	Peshawar	Middle and high schools (government and private sector)

Three primary methods are used to obtain consent: Directly at information meetings; through students relaying information to parents or schools communicating directly with parents. Inclusion criteria encompass an age range of 13–17 years and affiliation with specified educational institutions. The process aims to recruit a sample of students from either secondary schools, high schools, and/or vocational schools (see Table 1 above), though practical constraints may affect full representativeness, targeting 1000 participants at baseline and 750 at the second follow-up.

Process evaluation

To provide a qualitative and more nuanced understanding of the mechanisms behind the effect evaluation of the intervention, a convergent parallel mixed method design has been chosen. The mixed method design supplements the effect measurements with a process evaluation consisting of questionnaires and interviews for students and teachers.

In the questionnaire for the students, the design is informed by the RE-AIM framework [26], allowing to assess Reach, Effectiveness, Adoption, Implementation and Maintenance of the intervention, and draws upon established course evaluation survey instruments, particularly "The Learning Effectiveness Survey (LES)" [27] and "The Student Assessment of Learning Gains (SALG)" [28]. The questionnaire structure follows a traditional course evaluation format but places greater emphasis on students' learning experiences, teaching methods, and materials rather than solely focusing on perceptions of teaching quality. It aims to map how well students feel they have understood and utilized the presented teaching materials and content, as well as the effectiveness of chosen teaching strategies. The teacher questionnaire was similarly constructed utilizing the RE-AIM framework [26], with the objective of evaluating the implementation process from the teachers' perspective. It assesses teachers' capacity to deliver the intervention effectively, considering both their competencies and potential contextual barriers. Further, it examines teachers' perceptions of the teaching materials' utility and the content's comprehensibility. Further, process evaluation

interviews are supplementing both student and teacher questionnaires.

The aim of student interviews is to evaluate the intervention delivery process from the students' perspective, providing insights into possible effectiveness pathways, and contextual factors influencing implementation, identify barriers and facilitators in different educational settings (e.g. high schools versus vocational schools), and capture students' experiences with the intervention. Interviews with teachers investigate teachers' experiences with the intervention, exploring implementation challenges and programme perceptions, to uncover contextual influences across educational settings and inform potential enhancements to the intervention. The interviews also aim to complement and deepen the insights from the questionnaires in a more flexible and exploratory manner.

Intervention development

The intervention's development follows O'Cathain's guidelines on complex health interventions [25]. We use the behavioural change wheel [29] to specify intervention functions. To ensure adaption of materials and implementation strategies to each country's context the CICI framework has been used [30], crafting a thorough context assessment through questionnaires and workshops. Thus, the intervention design was developed through a participatory process involving regional partners and a global network of patient-oriented thyroid disorder organisations represented by TFI (Thyroid Federation International) and IGN (Iodine Global Network). The assessment revealed significant regional differences in school systems, teaching methods, curriculum structure, and overall educational frameworks, making a flexible intervention model necessary. Accordingly, a model with three modules, module A, B and C, has been developed to accommodate differences in system structures, time resources, teaching modalities and cultural norms.

In addition to raising awareness on iodine, a main goal of the study is to assess different teaching approaches and formats. The development of the modules and teaching components was grounded in active learning theories. These theories emphasize student engagement in the learning process through hands-on activities, critical thinking, and collaborative work, which have been shown to enhance knowledge retention and understanding [31]. Cooperative learning, a key aspect of active learning, was central to our approach. This method involves students working together in small groups to achieve shared goals, promoting positive interdependence and individual accountability [32, 33]. We incorporated cooperative learning assignments that required research, analysis, and critical thinking skills, allowing students to work collaboratively and present their findings to their peers. Additionally, a poster competition was implemented as part of the intervention. This student-driven activity encourages exploration, investigation, and creative design, fostering a deeper understanding of iodine intake concepts, mechanisms, and consequences. Such project-based learning approaches have been demonstrated to enhance student motivation and promote higher-order thinking skills [34].

Interventions components

The intervention and its components thus follow a flexible model consisting of three modules designed to adapt to the specific regional contexts of each study region.

The intervention components are designed to complement each other, providing a dynamic array of tools that teachers can use to plan their lessons effectively. The activities for each module are structured to build upon one another, offering a natural progression in the tasks. To maximize flexibility for individual teachers, who may face varying constraints or concerns such as curriculum requirements, students' level of knowledge or available resources, most elements and activities are designed to be independent of each other. This didactic structure allows teachers to select and implement the components that best fit their specific classroom needs and time constraints.

Furthermore, the module model is designed to enable comparison of the effectiveness of different teaching approaches. For instance, the study aims to evaluate the difference between lecture-based teaching and more active learning elements where students work in groups independently. This comparative aspect serves to test which approaches and methods are most effective in raising students' knowledge and awareness about iodine and its importance for health and well-being.

The intervention design thus serves a dual purpose: it provides practical, flexible teaching tools while also enabling the assessment of various teaching methods and their effectiveness in terms of short- and long-term retention of learning outcomes. This approach helps identify the most efficient strategies for future interventions.

As shown in Fig. 2 the intervention components comprise:

Module A (mandatory): Consists of Part 1 of a lecture (35 min), delivered as traditional in-class instruction, followed by Part 2 of a teacher-led review session (15–35 min), where exercises from Module A will be reviewed. The content of the lecture address bodily functions of iodine (metabolism, neurological development), health consequences of iodine deficiency, advised intakes and main dietary iodine sources operationalized in specific portion sizes, and exercises corresponding to the topics taught.

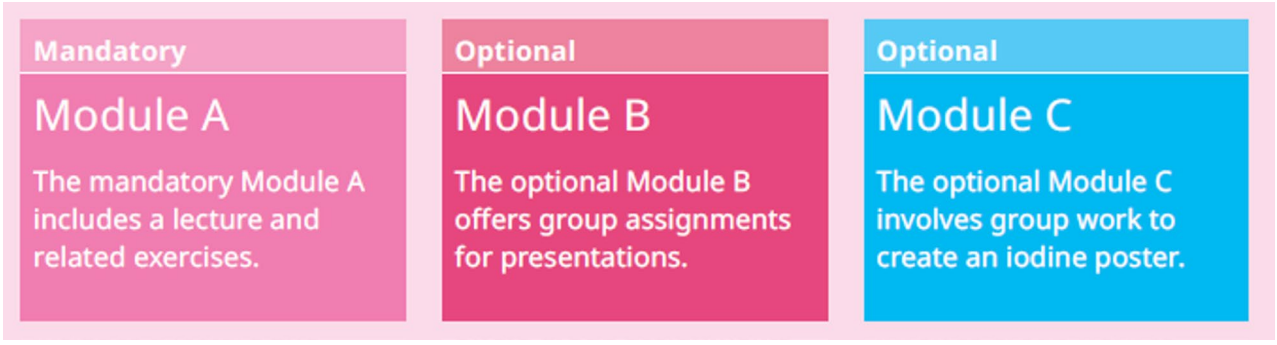

Fig. 2 An overview of the three-step learning model aimed at increasing knowledge and awareness among students on iodine and deficiency related health risks

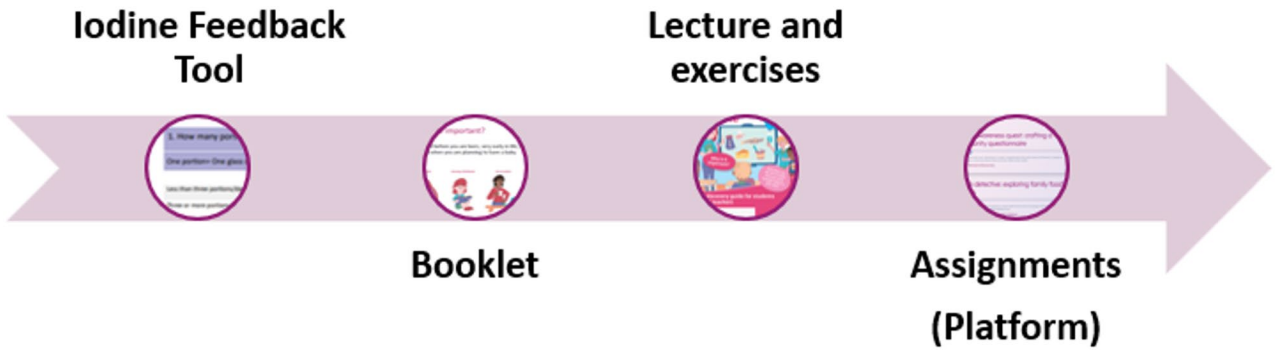

Fig. 3 Overview of the teaching resources made available to teachers at the intervention schools

Module B (optional): Consists of four active cooperative learning assignments [35], and an additional assignment on testing iodine content in iodised salt (this option is only available in Bangladesh[1]). Compared to the exercises in Module A, the assignments are more comprehensive tasks given to students. It involves a larger scope and may require research, analysis, creativity, or critical thinking skills. Students will work in groups, and results can be presented in class for fellow students.

Module C (optional): In groups, students are given the assignment to design a poster for an imagined national campaign on the importance of iodine. Students will be provided with guidelines and examples of campaign posters from actual campaigns for inspiration.

Regions have the option to organise local or regional competitions among participating schools, or school leadership can select a local winning poster. Students' efforts are recognized through certificates, and there is an opportunity to win prizes for best campaign poster. The regional management team collects all posters for evaluation, with assessment conducted by both the classroom teachers and/or scientists from the regional management.

[1] The test kits used for this exercise are distributed by UNICEF, which follows regulations restricting distribution to European countries. In Pakistan, this assignment was not possible as the import of kits was prevented by certain limitations.

Teaching resources

The following teaching resources and materials will be provided in intervention schools (see Fig. 3).

- The Iodine Feedback Tool
- A booklet aimed at students presenting module A, B and C, all themes taught in the lecture, glossary, exercises, assignments and extension tasks
- A PowerPoint presentation outlining the topics and exercises to be covered in module A
- Four educational posters with main messages and key information
- Online resources (including descriptions of assignments in module B and C) for teachers and students at ABC of Iodine Platform, an online learning forum at the EUthyroid2 website (https://www.euthyroid2.eu)
- A teachers' guidelines manual

The Iodine Feedback Tool: The Iodine Feedback Tool is designed to provide participants with personalized feedback broadly indicating their dietary iodine sources. It is intended to stimulate awareness and interest rather than serve as a sensitive method for assessing iodine intake. The tool comprises four questions focused on key dietary sources of iodine: iodised salt, iodine supplement use, milk and dairy products, and fish. Based on students'

responses, they receive automated feedback on their iodine intake behaviours. This feedback also includes recommendations for optimal portion sizes of the most important iodine-rich foods. The tool is based on a validated digital iodine-specific dietary screener [36] and was adapted for the purpose of the study and the specific regional implementation contexts.

The booklet: The booklet is a central resource in the classroom, consolidating all learning materials in one accessible format for students. It includes overviews and summaries of lecture topics, along with exercises for 'module A' that provide spaces for students to write answers and select options. Additionally, it contains assignments for modules B and C, as well as extension tasks, serving as both a reference and a workbook.

Lecture (PowerPoint presentation or educational posters): The lecture addresses all themes necessary to achieve the intended learning outcomes (see Appendix 1). The PowerPoint presentation features individual slides for each topic, with supporting information and explanations in the notes section for the teacher's use. Answers to 'module A' exercises are included in the slides or notes and can also be found on the ABC of Iodine Platform. If the educational posters are used during the lecture, they highlight key topics and information aligned with both the PowerPoint presentation and booklet content. Additionally, the educational posters can be printed and hung in the classroom for enhanced learning.

The ABC of Iodine Platform: The online platform is the main entry for enrolled schools and provides teachers and students with all information and materials that they need to participate in the project and conduct the intervention. The platform presents an overview of the intervention elements and teaching materials, aiming to clarify the project's organisation for both teachers and students. It displays available teaching resources and classroom materials, which can be used for lesson planning and implementation. The platform is designed to provide access to teachers' guidelines, intended to support the delivery of intervention content. It also allows students to access classroom materials. Furthermore, the platform is instrumental in data collection, serving as a tool to gather online data at T1, T2 and T3.

Teachers' guidelines

The teachers' guidelines provide a framework for the teachers at enrolled schools to implement the intervention. The guidelines include:

1. An overview of the learning programme and didactic design, outlining the educational approach, and the design and structure of the intervention.
2. The Intended Learning Outcomes, specifying the knowledge and skills students are expected to gain (see Appendix 1).
3. A description of teaching resources and materials, including the booklet, lecture materials (the PowerPoint presentation and the posters), and the Iodine Feedback Tool.
4. Suggested lesson structures for the three modules (A, B, and C), with information on duration and preparation requirements for each.
5. Answers to exercises and evaluation criteria to assist teachers in assessing student progress and understanding.

The aim is to equip teachers with the necessary tools and information to effectively deliver the intervention, ensuring consistency in implementation across different educational settings.

Outcomes

Primary endpoint

The primary endpoint is change in iodine awareness assessed from baseline (T1) to 2–4 weeks follow-up (T2) and again at 6–8 months follow-up (T3). As a secondary endpoint, changes in intake of iodine-rich foods are measured by a food frequency questionnaire from T1 to T2, and T3.

Sub-group analyses

Secondary endpoints are change in the following measures from baseline (T1) to 2–4 weeks follow-up (T2) and again at 6–8 months follow-up (T3):

1. Iodine awareness scores across different teaching methods.
2. Intake and consumption frequency of iodine-rich foods across different age groups (13–14, 15–16, 17y) and genders.

Further, differences in iodine awareness improvement between vocational schools, high schools and secondary schools will be analysed, and the correlation between increased awareness scores and teaching methods will be evaluated using pre- and post-intervention assessments. Notably, the long-term retention of iodine knowledge and awareness at T3 will be assessed and compared to T2 scores.

Sample size calculation

Each region aims to recruit 750 students aged 13 to 17 years. Ideally, students will be recruited from three different types of schools, covering low, medium, and high levels of education. The 250 students for each school type are derived from a power analysis, which assumes a

difference of two points in the awareness score between the intervention types with a standard deviation of 2.5 points, a power of 80%, an intra-class correlation coefficient of 0.4 and a total number of 22 classes.

The intervention design includes three different possible combinations of teaching components. All students are required to participate in module A and complete the associated exercises as this component is mandatory. Module B and C are voluntary, and it is decided by the teachers if they will be used. Thus, the following combinations of intervention components are possible: only A, A + B, A + C, A + B+C.

Exposures: The current state of knowledge precludes definitive determination of scenario-specific comparisons. The primary research objective is to assess whether combining module A with module B and/or C produces a measurable benefit compared to module A implemented independently. The main comparative analysis will therefore examine the outcomes of A+(B and/or C) versus A alone, enabling a systematic evaluation of potential intervention synergies.

Measurements

All measurement tools have been developed in English by the research team and then translated into local languages by regional partners.

Iodine awareness questionnaire: To assess iodine awareness, the research team developed the "Iodine Awareness Questionnaire" (IAQ). The IAQ was subsequently translated for each participating region. The questionnaire is designed to measure three conceptualized overarching dimensions: (1) knowledge of iodine, (2) attitudes towards iodine, and (3) ability to apply iodine-related knowledge. An overall IAQ score, as well as subscale scores, will be calculated by summing the internally weighted scores for correct responses, while incorrectly answered items will be subtracted according to their corresponding weights. Students will fill out the IAQ at T1, T2 and T3 (see Fig. 4). Socioeconomic

Status questionnaire (SES): Background variables such as age, gender, school type and grade, household composition and level of digitalization, parents' level of education and employment status, and basic elements of dietary patterns and level will be collected. Students will fill out the Socioeconomic status questionnaire at T1.

Iodine-food frequency questionnaire: To assess the dietary intake of key iodine sources, the research team developed an iodine-specific food-frequency questionnaire (i-FFQ) for enrolled students. This i-FFQ was adapted from a previously validated questionnaire used to evaluate iodine intake in Norwegian pregnant women [37]. The instrument comprises eight questions that probe the frequency of consumption of known iodine sources, including iodised salt, iodine supplements, milk and dairy products (yoghurt and cheese), eggs, fish, and seaweed and algae. To account for regional dietary variations, country-specific questions were incorporated, addressing items such as plant-based milk alternatives, goat cheese, and fortified foods, to ensure an assessment of iodine intake across different cultural and dietary contexts. Students fill out the i-FFQ at T1, T2 and T3.

Process evaluation questionnaire for students: A process evaluation questionnaire has been developed. The questionnaire incorporates standard items to evaluate Knowledge, Skill, and Attitude [27], supplemented by flexible items tailored to the specific teaching resources being assessed (e.g. the booklet, the lecture, the online resources, etc.). Knowledge and Skill evaluations are based on the intended learning outcomes (see Appendix 1) established for the teaching programme. Additionally,

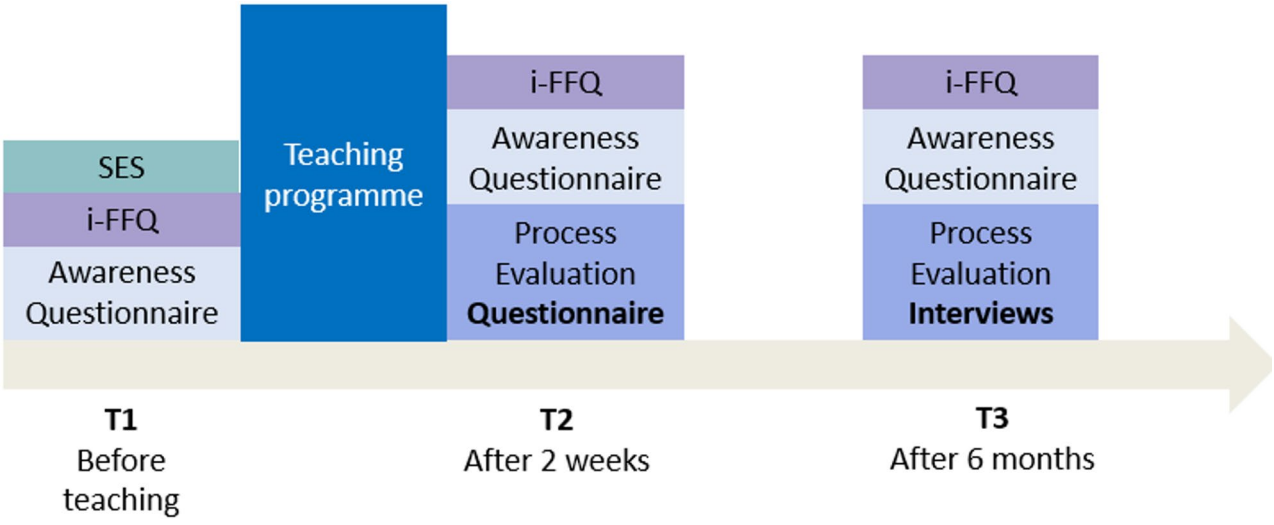

Fig. 4 Overview of background, effect and process evaluation measurements for students

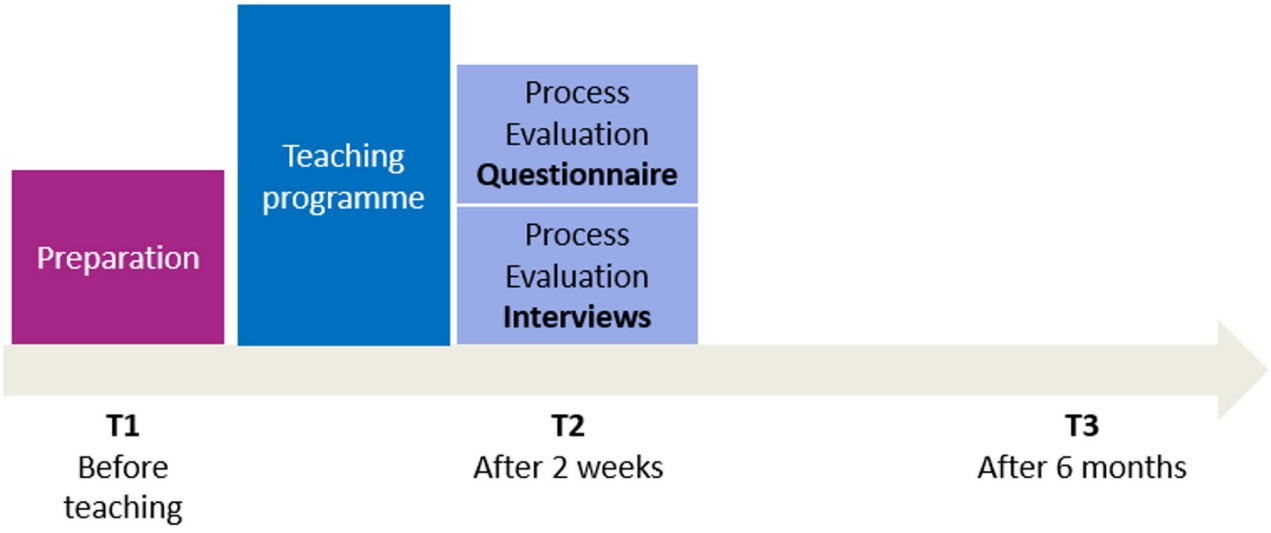

Fig. 5 Overview of process evaluation measurements for teachers

the following elements from the RE-AIM framework, focusing on factors relevant to students, was integrated: (1) Perceived usefulness and satisfaction with teaching materials, (2) Comprehensibility of content in the teaching material and (3) Technical impediments, such as internet connectivity issues or difficulties accessing The ABC of Iodine Platform. Students fill out the process evaluation questionnaire at T2.

Process evaluation interviews with students: An interview guide for process evaluation interviews has been developed. The interview guide includes lead and in-depth questions focused on students' experiences with intervention components and teaching materials, their attitudes towards the programme, and their awareness of iodine and its consumption. To address varying levels of experience in qualitative research among regional partners, detailed instructions on conducting semi-structured interviews will be provided. The interviews will be conducted by the regional partners in the relevant local languages, audio-recorded, transcribed, and subsequently translated into English for the purpose of data analysis. A content analysis will then be carried out [38].

The process evaluation interview will be conducted with four students in each region at T3.

Process evaluation questionnaire for teachers: To assess the implementation process from the teachers' perspective, the questionnaire first asks which elements of the intervention they used and how much time they spent on them, alongside other dimensions of implementation.

To evaluate the implementation process from the teachers' perspective, a questionnaire was developed. The questionnaire first asks which elements of the intervention they used and how much time they spent on them. Next it assesses teachers' ability to deliver the intervention effectively and examines teachers' perceived usefulness and satisfaction with the teaching materials, as well as the comprehensibility of the content. The survey also addresses technical challenges, such as unstable internet connections or difficulties accessing the online platform, to identify potential barriers to implementation. It explores how well the intervention fits within the existing curriculum and alongside other subject obligations, considering time constraints that may affect implementation fidelity. It investigates whether teachers have engaged in discussions about iodine with colleagues and teachers' opinions on the scalability of the intervention for nationwide implementation, providing insights into the intervention's reach and possible broader adoption. Finally, the questionnaire assesses whether teachers feel adequately qualified to implement the intervention as intended. Teachers fill out the process evaluation questionnaire at T2 (see Fig. 5).

Process evaluation interviews with teachers: Similarly, qualitative interviews will be conducted with teachers to evaluate the intervention implementation process from their perspective. The semi-structured interviews explore teachers' experiences with the intervention components, perceived barriers to implementation, and attitudes towards the program. This approach aims to identify contextual factors influencing implementation across the different educational settings and provide insights into potential improvements. The process evaluation interview will be conducted with two teachers in each region at T2.

Data management

Personal identifying data including informed consents will be exclusively collected and administrated by the responsible study regions. Survey data (IAQ, Socio-economic background questionnaire, Food Frequency

Questionnaire and process evaluation questionnaire) and feedback tool submissions can be collected paper-based and digitally using an online survey tool provided by the consortium coordinator. Paper-based questionnaires are subsequently transferred to the online survey. Interview data will be uploaded to a cloud service hosted by the University of Greifswald. Extracted data from the online survey tool and the interview data will then be stored in a PostgreSQL database and servers provided by the consortium coordinator.

The scientific analysis of the collected data is carried out by the researchers of the consortium. Researchers outside the consortium have the option of applying for the data obtained. In this case, the data will be anonymized and only the data required for the respective research question will be compiled into a project-related evaluation data set and made available for the research project, taking particular account of any resulting re-identification risk.

Statistical analyses

Since the students are clustered in regions, schools, and classes, mixed models with random intercept will be applied. To examine the association between different combinations of intervention components and changes in iodine awareness and intake of iodine-rich foods, further co-variables will be considered:

1. School type (vocational school, high school or secondary school)
2. Gender of the student
3. Age of the student (13-14, 15-16, 17y)
4. Socioeconomic status of the student (SES)

These variables can be either seen as (a) confounders or (b) effect modifiers. For (a) we will adjust for these covariates to estimate the overall effects of the interventions on changes in awareness and food intake independent of the educational level of the school, age, gender, and SES. For (b) we will test interactions of the intervention with educational level, age, gender, and SES on the changes in awareness and food intake. If we observe significant interactions, we will explore and visualise effects of the intervention on the changes in awareness and food intake for different levels of the effect modifier (e.g. in boys and girls; for low, middle and high level of education).

Sub-populations: The main analyses will be conducted for all regions together, but it may be also of interest how the success of the interventions differ according to the study region. For this, we will conduct separate analyses for each of the study regions.

Discussion

Insufficient iodine intake remains a global public health challenge, affecting an estimated 2.2 billion people worldwide [39]. Despite significant progress in many regions, iodine deficiency disorders (IDD) continue to pose risks, particularly for vulnerable populations such as young women and children [40]. This intervention study addresses a critical need by developing and evaluating strategies to increase iodine awareness and intake among adolescents and thus possibly reduce the risk of iodine deficiency during future pregnancies.

The complex approach, combining educational intervention with dietary assessment tools like the iodine-specific food-frequency questionnaire (i-FFQ), contributes valuable insights to the existing body of knowledge. By targeting adolescents and incorporating region-specific considerations, the study addresses knowledge gaps in current intervention strategies [41].

This research will provide a foundation for designing effective, large-scale interventions tailored to diverse population groups. By systematically evaluating the impact of educational strategies within different school settings and demographic subgroups, the study will generate valuable insights into which approaches most successfully enhance knowledge and foster behavioural change related to iodine intake. A key objective is to identify, map and evaluate intervention components that could be scaled up and adapted for broader national awareness campaigns. These campaigns would particularly focus on vulnerable populations, such as adolescents, individuals from lower socioeconomic backgrounds, and those with limited access to nutrition education or healthcare resources. By identifying the most effective educational approaches and communication methods, the intervention will contribute to the ongoing global efforts to combat the lack of awareness concerning iodine deficiency and thereby improve public health [42]. Ultimately, this work contributes to global efforts to combat iodine deficiency by enhancing public awareness, promoting preventive nutritional practices, and influencing health policy to protect the wellbeing of both current and future generations.

Appendix

Intended Learning Outcomes for the lecture and exercises in Module A

1. Describe the basic principles of the bodily functions of iodine
2. Describe iodine's significance for health and growth
3. Explain the importance of sufficient iodine levels during pregnancy
4. List iodine WHO recommendations regarding iodine intake for different age groups

5. Explain the health consequences of iodine deficiency
6. Identify good iodine sources in the diet
7. Apply iodine knowledge in healthy dietary choices

Acknowledgements
The authors would like to thank Joyce Greene, Senior Advisor, and Deqa Jama, Communications, both Iodine Global Network, for their comments on the conception and design of the intervention teaching materials; and to Jennifer Taylor and Rebecca Murphy for their assistance with pretesting the materials.

Clinical trial number
ClinicalTrials.gov number: NCT06769009. Registered 2025-01-08. The EUthyroid2 project comprises two parallel intervention components implemented in ambulatory care and educational settings. Both components aim to improve knowledge, awareness, and iodine-related practices among key target groups. The ambulatory care intervention is conducted as a randomised controlled trial, while the educational setting intervention, which is the focus of the present protocol, follows a non-randomised, uncontrolled design.

Authors' contributions
Bodil Just Christensen, Natalia Cecon-Stabel, Synnøve Næss Sleire, Lisbeth Dahl, Freia De Bock and Gitte Ravn-Haren contributed to the study conception and design. Bodil Just Christensen, Signe Skovgaard Hansen and Gitte Ravn-Haren drafted the manuscript. Remaining co-authors took part in revising the manuscript. All authors substantially contributed to the manuscript and approved the final version.

Funding
The EUthyroid2 project is co-funded by the European Union's Horizon Europe programme (Grant agreement number 101095643) and by UK Research and Innovation (Grant numbers: 10068239 (Queen's University Belfast) and 10062205 (University of Surrey)).

Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
The study was reviewed and has received the general ethics approval from the Ethics Committee of the University Medicine Greifswald (Reference Number: BB103/23) and the local ethics committees of the collaborating institutions: Ethical Review Committee of Bangladesh University of Health Sciences (BUHS/ERC/EA/24/65), Cyprus National Bioethics Committee (EEBK/EIT/2024/53; 22809038/22809039; 22353878), Ethics Committee Islamia College Peshawar (04Zool/Euthyroid2/ICP), Ministry of Health Slovenia, Commission of the Republic of Slovenia for Medical Ethics (0120–327/2024-2711-3), Queens University Belfast Faculty of Medicine, Health and Life Sciences Research Ethics Committee (MHLS 24_191), University of Surrey, Faculty of Health and Medical Sciences School of Biosciences (Ref: 1301). ClinicalTrials.gov number: NCT06769009. At the time of enrolment, all eligible participants will provide written informed consent after receiving a detailed explanation of the study. In certain locations an opt-out consent process may be applied in accordance with local regulations.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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Received: 12 October 2025 / Accepted: 19 March 2026
Published online: 01 April 2026

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