Socio-Scientific Issues in Teacher Education –
A Methodological Approach to Communicating
the Ambivalence, Multi-Perspectivity and Complementarity of
Sustainable Development Claims

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Decisions in terms of sustainable development cannot be made solely on the basis of scientific facts, but must also include ethical, cultural, ecological, socio-political and economic aspects in order to achieve a balance between – often contradictory – demands. Socio-scientific issues (SSI), i.e. problems at the interface between scientific concepts and social conditions, are at the center of an innovative teaching approach that is used in the basic and advanced training of educators. The fact-based decision-making supported by scaffolding techniques in a real-world context provides an insight into the multidimensionality of sustainability and supports the development of sustainability-related teaching skills in (future) teachers. The article uses specific teaching examples to provide an insight into the teaching concept and discusses the potential for use in the qualification of teachers and in other fields of adult education based on the findings from pilot projects.

The Professionalization of Teachers as a Specific Feature of Sustainability-Related Adult Education

Embedding education for sustainability in the formal education system

The formal education system holds a key position in the endeavor to create a sustainable future. Hardly any other social context reaches broad sections of the population almost across the board and offers the opportunity to systematically support the acquisition of competences and the development of a critical and reflective world view in young people over a period of years. The Austrian Ministry of Education therefore considers competence-orientated teaching to be crucial for understanding the complexity of sustainability on the one hand and for supporting a sustainable way of life among pupils on the other. As part of the Austrian Strategy for Education for Sustainable Development, all levels of formal education are seen as fields of action for the development and implementation of the concept of sustainability in the sense of a "process in progress". Cyclical quality assurance in the school sector and the professionalization of teachers are key aspects of education for sustainable development. Accordingly, further development and co-operation across the educational landscape are deliberately at the forefront of the Austrian strategy for sustainable development (Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management et al., 2008). In the UNESCO global action programme on "Education for Sustainable Development for the implementation of ESD in the period from 2020 to 2030", competence development among teachers and multipliers is also identified in Priority Action Area 3 as an important starting point for more effective follow-up (https://www.unesco.at/en/education/education-2030/education-for-sustainable-development/global-action-programme-on-education-for-sustainable-development).

These documents also list specific educational principles that correlate with the learning fields formulated in the Austrian agenda. With regard to Austrian curriculum content, these policy papers regard education for sustainable development as a fundamental and regulative principle. True to the interdisciplinary basic idea, "cross-curricular references" are of particular importance. A variety of approaches to the topic and activating, participatory teaching methods are explicitly considered desirable.

Education for sustainability in the Austrian curricula

The term sustainability was not used in the primary school curriculum until 2023. In the new curriculum, which comes into force in 2023, "environmental education for sustainable development" is explicitly mentioned as a consistent teaching principle. However, the intended learning content and competences are limited exclusively to ecological perspectives. In Austrian secondary schools, the topic of sustainability is traditionally addressed primarily in the subjects of geography and economics as well as biology and environmental studies, while other subjects such as chemistry contain curriculum content that can be related to sustainability topics. Apart from these subjects, each type of school formulates general educational goals that are often related to the topic of sustainability. Overarching teaching principles are used for cross-curricular and cross-school type networking, in which environmental education for sustainable development in particular addresses sustainability. If we take a general look at the curricular anchoring of education for sustainability in Austrian curricula, we can find many approaches for dealing with sustainability topics in the classroom. However, the joint thinking of the ecological, economic and social dimensions and cross-curricular references called for in the strategy papers can only be recognized to a limited extent. In practice, the flood of information and overly broad formulations can also lead to implementation difficulties and obstacles in the classroom. As an explorative preliminary study on pupils' images of the future (Heinrich et al., 2005) shows, interviews with pupils reveal desiderata for sensitized, everyday-conscious, innovative,

authentically credible, networked and respectful teaching in the sense of Education for Sustainable Development, and thus the need for continuous further training for teachers.

Challenges for the professional development of teachers

For the initial and further training of teachers, this means that teaching approaches are needed that enable sustainability education to be localized in the respective subject with a connection to curricular requirements and at the same time make it possible to address cross-curricular aspects and children's lifeworld contexts.

However, this requires the qualification of teachers in sustainability education to be multi-dimensional and multi-perspective in several respects.

- *Multi-perspectivity of the sustainability dimensions*
  An understanding of sustainability in the sense of the 17 UNESCO goals encompasses economic, ecological and social dimensions. Education for sustainability must therefore think beyond the narrow subject reference and address ambivalences and contradictory requirements between the individual dimensions.
- *Multidimensionality of the competences to be acquired*
  In order to be able to act in terms of sustainable development, transversal skills (critical thinking, ability to cooperate, discursive and argumentative skills, ability to make well-founded decisions taking into account professional, social, ethical and cultural aspects) are required in addition to subject-specific scientific skills. In addition, the ability to reflect on personal attitudes, value systems and moral components is necessary to enable social dialogue on sustainability issues.
- *Multi-perspectivity of the teacher role in CPD*
  In professional education and training, teachers take on two roles: On the one hand, they are learners who themselves acquire content, competences and attitudes towards sustainability in relation to their own person. On the other hand, the perspective of the participants as (future) teachers must also be considered and the transfer of the knowledge and skills gained must be prepared by means of didactic preparation in the classroom. In the design of initial and further training programmes, care must also be taken to ensure that teachers reflect on their own ideas about teaching and learning and that their self-efficacy is taken into account. (cf. Maass & Engeln, 2018, 2019). This combination of "learning" and "teaching" perspectives poses a particular challenge for those fields of adult education that aim to qualify people working in educational contexts.

Socio-Scientific Issues as a Methodological Framework in Education for Sustainability

The aim of teacher training must therefore be to use appropriate teaching formats to address the various content-related perspectives of sustainability and the necessary competence dimensions for sustainable development as personal learning fields for teachers and at the same time to develop a methodological spectrum for teaching work with pupils (Maass, 2011; Rauch & Steiner, 2013).

The SSI approach

The teaching approach of "Socio-Scientific Issues Teaching" (Zeidler & Kahn, 2014), which is based on a comprehensive understanding of "scientific literacy", offers a framework – also confirmed in evaluation studies – for developing competences for evidence-based decision-making in socially relevant issues, including ethical and social perspectives (Hadjichambis et al., 2020; Jarman & McClune, 2007; Kläy et al., 2015; Ratcliffe, 2003).

In order to use the SSI approach in the professionalization of teachers and to address the challenges mentioned above, it was necessary to supplement the model, which was primarily designed for direct teaching use in schools, with activities that serve to reflect on one's own attitude and values in relation to the topic and to take up the interplay of "learning" and "teaching" perspectives in a structured way.

ENSITE – Environmental Socio-Scientific Issues in Initial Teacher Education

Project objectives and structure

The Erasmus+ project ENSITE, in which two of the authors were involved, was carried out from 2019 to 2022 and aimed to develop and promote the environmental citizenship of future teachers and related teaching skills (European Commission, 2019; Evagorou et al., 2020). Teams at eleven European universities contributed their expertise to develop 12 teaching modules on SSI. The modules are divided into those that focus on learning (in the sense of developing competences in dealing with SSIs; modules 1-6) and those that focus on teaching (in the sense of acquiring pedagogical skills to support learners in developing their SSI competences; modules 7-12). The content of the modules ranges from explaining the characteristics of SSI to methods and examples, links with existing curricula and assessment. The individual modules were developed in the various teams according to a standardized structure: They each contain an introductory presentation, detailed overview and process, worksheets and materials. Each module was reviewed by a team other than the one preparing it and, after incorporating suggestions for improvement, was tested in practice by a third team. The feedback from these tests was also taken into account in the final version. All documents and materials are available for free download on the project website in several European languages: https://icse.eu/ensite/ .

Table 1. Overview of the modules in the ENSITE project.

	Modules with focus on LEARNING	
01	The Nature of SSI	Using concrete examples relevant to everyday life, participants learn what "environmental socio-scientific issues" are and find out about the connections between maths and science lessons and political education
02	Reasoning, Argumentation & Critical Thinking	Using reports and articles from popular media on STEM topics, skills are taught that are necessary for an informed and critical approach to scientific reporting
03	Collecting Data	Participants develop skills in planning and conducting surveys and in data modelling
04	Analyzing Big Data	The participants explore the structure of data sets and examine different visualizations of the same data, each telling a different story
05	Decision-making	Using the example of world nutrition, decision-making is experienced as a weighing up of different (scientifically based and personal) perspectives
06	Negotiating the social, political or ethical dimensions in SSI	Using mobility as an example, the participants use their own experiences to identify different dimensions of SSI that need to be taken into account in order to find socially sustainable solutions to pressing issues
	Modules with focus on TEACHING	
07	Aims of SSI and Curriculum	The module helps to find points of reference for SSI lessons in the existing maths and science curricula and to develop corresponding courses
08	Beliefs on teaching SSI	
09	Designing an SSI lesson I, focus on didactics	The participants develop ideas for the design of SSI units using the example of the "plastic dilemma" and draw on approaches from research-based learning and education for sustainable development (ESD)
10	Designing an SSI lesson II, focus on methods	How can existing teaching units or projects be redesigned using modern methods to create teaching units that convey the importance of maths and science skills in an appealing way?
11	Scaffolding	Participants become familiar with the scaffolding method, which helps learners to plan and implement the next step in the learning process when faced with very open-ended problems
12	SSI and assessment	This module shows how learning progress can be assessed in SSI lessons

Note. Adapted from ICSE – International Center for STEM Education, by University of Education Freiburg, 2024, ENSITE – Environmental socio-scientific issues in initial teacher education (https://icse.eu/ensite/).

Overview of the modules

The ENSITE project has resulted in 12 teaching modules on environment-related SSI. The individual modules contain specialized knowledge on various environmental topics, but above all they support the seminar participants in developing skills in dealing with and teaching such complex topics and in reflecting on their own attitude to sustainability in relation to the teaching process. **Table 1** provides an insight into the objectives of the respective teaching modules.

Selected Teaching Modules

In the following, we would like to present the modules developed by the authors of this article in more detail.

Scaffolding

The "scaffolding" method follows a constructivist learning paradigm; learning is understood as an active, situational, constructive and social process. Learning does not simply take place step by step from the simple to the more complicated, but rather corresponds to grasping a rough structure that is recognized in ever greater detail in the course of the learning process.

Scaffolding is an educational concept developed by the American cognitive psychologists Wood et al. (1976). The idea behind it is to use authentic, complex problems for the learning process and to support the learner by initially providing orientation in the form of instructions, food for thought and other assistance ("scaffolding"). As soon as the learner is able to complete a certain subtask independently, this "scaffold" is gradually dismantled. This corresponds to a gradual transfer of responsibility from the teacher to the learner.

As part of the ENSITE project, we chose the example of the "forest" to teach the scaffolding methods. It seemed suitable in several respects: There is a lot of forest-related content in the national curricula. From the basics of plant growth to human utilization and connections with climate change, the forest offers a wealth of information.

The module is divided into three blocks (**Figure 1**):

Block 1 serves as an introduction to the topic: Firstly, the participants gain an impression of how different forests can look and what prior knowledge, beliefs and attitudes they bring with them. It shows from how many perspectives one can approach the forest (e.g. from the point of view of ecologists, foresters, recreationists, ...) and thus the quality of an SSI. Finally, the participants learn how references can be made to the curriculum.

Block 2 serves as an introduction to the scaffolding method. In the first step, individual tree species are used to analyze which site factors exist and how they affect the appearance and species composition of the forest. A look at the history of the earth is intended to show how forests and their distribution change and what conclusions can be drawn from this. In the final activity, the

complexity increases from exercise to exercise: in the first exercise, the framework is clearly defined, in the following exercises more and more dimensions of the SSI Forest are to be included. In the introductory exercise, the more suitable of two tree species is to be selected for a given location. At the end of the series of exercises, a decision is to be made on what to do with a forest site in a national park that has been affected by an avalanche. Should ecological, safety, economic or other aspects be prioritized? The participants should gather information, discuss, argue and reach compromises.

In Block 3, participants learn how to apply scaffolding themselves: A range of scaffolding techniques will be introduced. The participants analyze the activities from Block 2 and try to identify scaffolding elements. Finally, the participants themselves plan a teaching unit on a topic chosen from a pool of topics and a learning objective specified by the trainer, incorporating scaffolding methods.
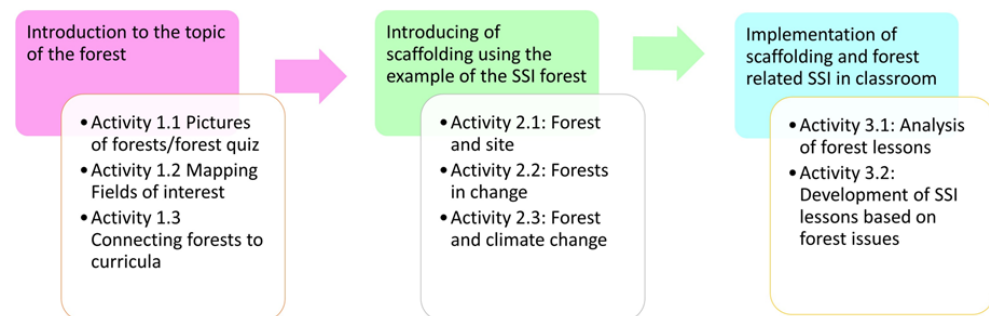
Figure 1. Flowchart of module 11.

Note: Structure and module plan of "Scaffolding" module. Own illustration.

The individual activities provided in this module were described in instruction cards for direct use in the training of teachers. **Figure 2** shows an example of such an instruction card. In addition, a guideline for the seminar leader was created for the module.
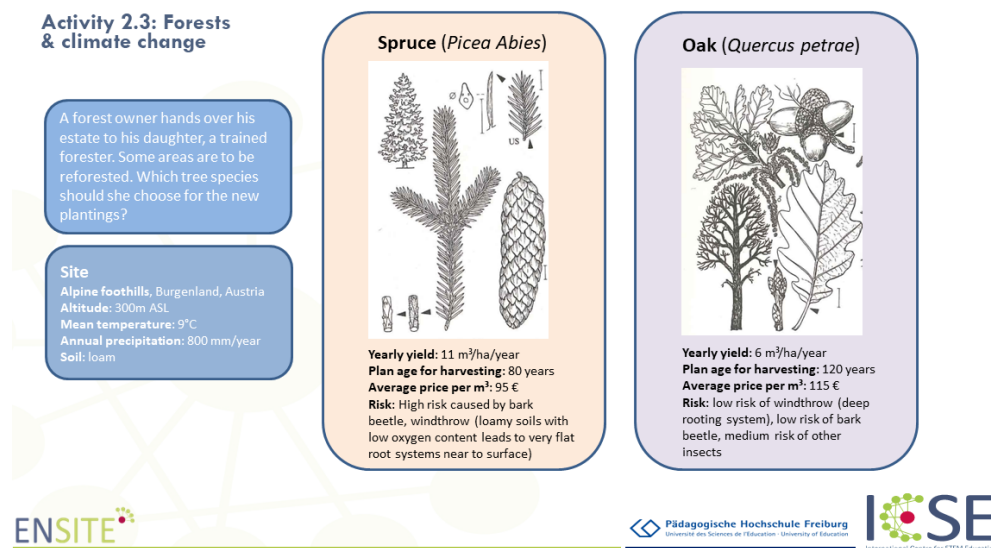
Figure 2. Example for scaffolding activity

Note: Instruction card for the "Forest and climate change" activity from the "Scaffolding" teaching module. Own illustration.

Dealing with social, political or ethical dimensions in SSI

In this module, the participants deal with the topic of mobility and learn about its potential as an SSI. The activities aim to recognise the connection between scientific knowledge and social negotiation processes using the topic of mobility as an example.

The introduction to the topic and the basis for the subsequent activities is provided by a role play in which different roles, thought patterns and values of decision-makers are experienced in a mobility-related problem. This is intended to sensitise the participating teachers to the different perspectives that need to come together in this problem area relevant to everyday life in order to develop socially sustainable solutions.

Reflecting on the values and attitudes behind their own mobility decisions and analysing their own mobility biography will lead them to identify social, political, ethical and ecological perspectives on mobility based on their own experiences. Participants make connections between mobility issues and curriculum content, sustainability goals and civic competences. They analyse SSI teaching elements on mobility and then develop their own exercises and lesson plans. In the concrete work on lesson activities, participants learn to take up current mobility-related topics from the children's local context and design SSI learning activities based on them.

The module consists of three sections divided into different activities. It includes lecture sections, group discussions, debates and student presentations. **Figure 3** provides an overview of the programme and the main content.
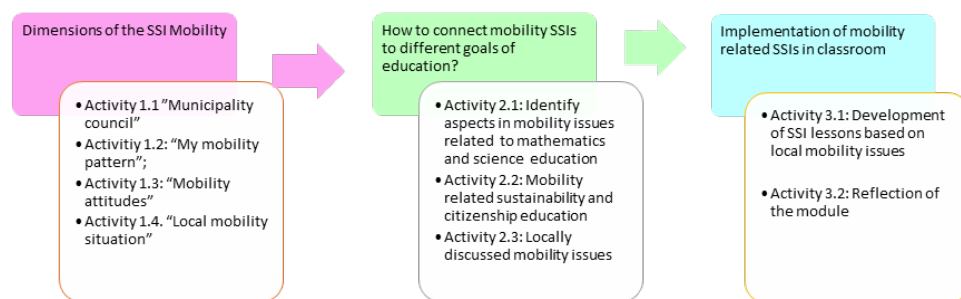

Figure 3. Flowchart of module 06

Note: Structure and module plan of the learning module "Negotiating the social, political or ethical dimensions in SSI". Source: own illustration.

Instruction cards for the participants (see **Fig. 4** and **Fig. 5**) and guidelines for seminar leaders were also developed for this module. The example given is a role-playing game, a tried and tested format in the context of SSI (Belova et al., 2015).

Figure 4. Example for activity in module 06

Note: Introduction for the "municipal council" activity. Source: own illustration.

Figure 5. Example for in-depths tasks

Note: Follow-up tasks for the "municipal council" activity. Source: own illustration.

Experiences From the Pilots

The development of the teaching modules was based on the theoretical background of "research-based design" in iterative cycles of design, collegial feedback, testing, evaluation and optimisation. Each module was tested and evaluated by two partner institutions on the basis of questionnaires.

The most important findings from the pilots are

- The participating teachers agree to a very high degree with the need to address sustainability topics in the classroom.
- Most of them state that they have increased their competences in dealing with sustainability topics and in teaching these topics.
- Most of them feel able to choose appropriate topics and didactic realisations for sustainability-related SSIs.
- The majority of them intend to include sustainability topics in their lessons in the future.
- Key suggestions for improvement in the development process concerned the need for additional structural aids and scaffolds to support the processing of complex SSIs and the reduction of complexity in the questions to be processed.

Potential of the SSI-Approach for Use in Other Adult Education Contexts

The piloting phase coincided with the peak of the COVID wave, which is why adaptations had to be made to the organisation of the test seminars. The planned courses in the regular teacher training programmes of the participating institutions were replaced, for example, by online seminars or test runs with smaller groups in a more informal setting. In addition to the originally intended target group of student teachers, other groups of participants, such as students of environmental systems science or educators at extracurricular learning centres, were also included in the testing of the materials and methods. It turned out that the SSI approach contains many elements that can also be helpful in the professionalisation of other occupational groups. In particular, those methods that are aimed at reflecting on one's own values and attitudes as a basis for professional work and that create awareness of different perspectives on sustainable development are also seen as enriching and helpful for their professional practice by participants who are not in the teaching profession.

Summary and Outlook

In the design and piloting of a total of 12 modules developed in the ENSITE project, it became clear what potential the SSI approach offers for the qualification of teachers. The focal points derived from the basic concept offer assistance for a wide range of challenges that teachers are confronted with in the targeted development and implementation of sustainability teaching in the sense of the 17 Sustainable Development Goals. In particular, the interdisciplinary, multi-perspective approach to sustainability issues is effectively supported by the range of methods. The findings from the pilots encourage us to further develop the approach specifically for use in adult education. In addition to methodological refinements, especially in the area of scaffolds, SSI can also be used for the qualification and further training of extracurricular sustainability educators such as national park employees, explainers in extracurricular learning centres or moderators of citizen participation processes.

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