International Centre for STEM Education

ENSITE
Environmental Socio-Scientific Issues in Initial Teacher Education

Guidelines for Open Learning Environments

Including Environmental Socio-Scientific Issues in Science and Mathematics Initial Teacher Education

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Executive summary

Within the ENSITE project, this document provides a set of guidelines to support the design of high quality learning environment for Initial Teacher Education (ITE), with a special emphasis on improving future science and mathematics teachers` Higher Education (HE) by including environmental Socio-Scientific Issues (SSIs) in ITE. The recommendations are based on a literature review including political documents and expert reports about Quality Assurance in Higher Education, Teacher Qualifications and SSI. The guidelines are organised according to three main domains: content, methods and resources.

Introduction

These guidelines have been developed within the Erasmus+ project ENSITE (Environmental Socio-Scientific Issues in Initial Teacher Education). This project intends to make a contribution in the preparation of science and mathematics teachers by developing their competences in dealing with environmental SSI themselves and in acquiring teaching skills to support their students in developing these competences. Prospective mathematics and science teachers need to take into account that learning “of and about” science” (Osborne and Dillon 2008) includes social, cultural and ethical dimensions thereby fostering young people`s understanding of science as well as its implications and limits.

Within that context, the main objective of this document is to support teacher educators in the development of high quality learning environments (OECD, 2009; OECD, 2011) for teacher initial education with a focus on teaching environmental SSIs in mathematics and science teaching (further referred to as science).

Special attention will be paid to SSI applied to science and mathematics teacher education, quality standards in higher education and the integration of Open Educational Resources (OER). An extended theoretical foundation based on the specialised literature and in a review of referents for quality assurance and science and mathematics teacher qualifications may be found in Ariza, Quesada and Abril (2017).

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What are Socio-Scientific Issues?

The nature of Socio-Scientific Issues

Socio-Scientific Issues (SSI) require students to engage in dialogue, discussion, and debate. They are mainly controversial in nature but also require forming opinions and making decisions including moral, ethical or social reasoning issues (Zeidler and Nicols 2009). Most of the time, people have to deal with these issues through incomplete information because of conflicting or incomplete scientific evidence and incomplete reporting. Often these issues involve a cost-benefit analysis in which risk interacts with ethical reasoning (Ratcliff and Grace 2003). Consequently, such contexts especially serve the purpose of educating for scientific citizenship (Owen et al. 2009).

An example of an SSI in the area of biology is the question whether vaccination against measles should be obligatory or not. Opponents of vaccination ignore scientific evidence on vaccination and epidemics, and tend to refer to their own evidence and experts. In order to follow the discussion on this issue as an active citizen, young people need to learn about such issues and how they are influenced by ethical, moral and cultural issues.

We suggest that when dealing with SSIs, we suggest following a cyclic process including steps like search for information and (risk) analysis of sources of information, discourse about (possibly) contradicting scientific results and ethical, social, cultural reasoning (Zeidler and Nicols 2009). Particularly the difference between scientific results and conclusions has to be made clear (Ratcliff and Grace 2003). A possible resulting process is shown in Figure 3.

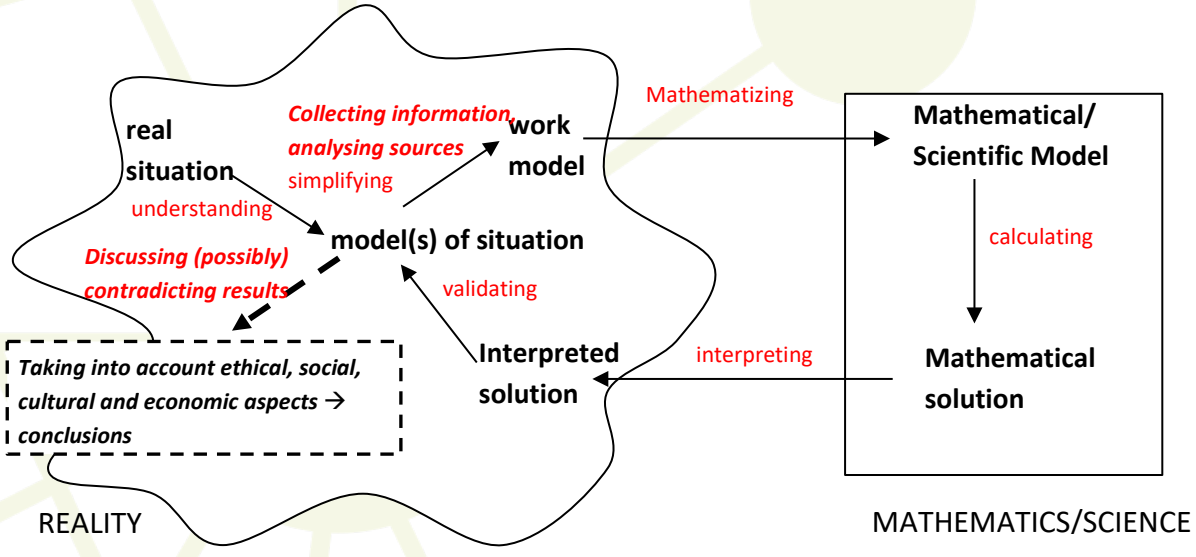

Fig. 3. Working process for socio-scientific issues (Maass, Doorman, Jonker and Wijers 2019)

Research has shown that SSIs can be used as contexts for learning scientific content (Applebaum et al. 2006; Walker 2003; Zohar and Nemet 2002) and for understanding the nature of science (learning 'about science', see part 1) and for citizenship education (Herman et al. 2018; Radakovic 2015; Sadler et al. 2007). In this respect, the authors highlight the following important aspects

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when dealing with SSIs: (1) recognizing the inherent complexity of SSIs, (2) examining issues from multiple perspectives, (3) appreciating that SSIs are subject to ongoing inquiry, (4) exhibiting skepticism when presented with potentially biased information.

How to include Socio-Scientific Issues in STEM teaching

One approach that has proven to be helpful in science education is inquiry-based learning (Knippels and van Dam 2017). Consequently, combining inquiry-based teaching approaches with SSIs seems to have the potential to promote active citizenship in STEM-education.

By IBL, we refer to a student-centered learning paradigm in which students are involved in inquiry-related processes like observing phenomena and creating their own questions, selecting mathematical approaches, creating representations to clarify relationships, seeking explanations, interpreting and evaluating solutions, and communicating their solutions (Dorier and Maass 2014).

On the teacher's part, pedagogies evolve from a 'transmission' orientation, in which teacher explanations, illustrative examples and exercises dominate and are not questioned, towards a more collaborative orientation. The teacher's role includes making constructive use of students' prior knowledge, challenging students through probing questions, managing small group and whole class discussions, encouraging alternative viewpoints, learning from mistakes and helping students to make connections between their ideas (Swan 2005, 2007).

Definitions of IBL, however, differ in the degree of autonomy given to students in the selection of problems and in the responsibility for inquiry processes (Artigue and Blomhøj 2013). In our approach to IBL, we refer to a socio-cultural approach in which learning needs to happen in interactive social classroom settings (Radford 2010) and the teacher takes an active role by creating learning situations inspired by inquiry-related processes. Teachers who take these active roles in guiding their students are more effective than those who take passive roles and let students discover on their own (Askew et al. 1997; Swan 2006).

For the purpose of promoting citizenship education, students need to have an active role, similar to that in IBL, for developing critical thinking and decision making, for learning to take into account ethical, social and cultural aspects, and for learning to deal with controversy (Zeidler and Nicols 2009; Geiger, Goos and Forgasz 2015). Already Dewey (1916) emphasized the connection between IBL and education serving democracy.

The following guidelines are organised according to three big domains: content, methods and resources.

Content

In order to ensure appropriate, relevant and high quality content, the modules for teacher initial education should:

- **Keep in mind the target audience** and adapt to their needs and expectations (teacher educators and their respective student teachers at higher education level).

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- **Select relevant topics.** A topic is considered relevant when it deals with key issues to prepare teachers for the specific challenges encountered when including environmental SSI´s in science teaching. When developing the learning environments, it is important to reflect on the relevancy of the selected topics and explain their value and usefulness for prospective teachers to enhance science and mathematics learning in with environmental issues relevant to society.

- **Differ between two different dimensions**: They support teachers in (A) developing competences in dealing with environmental SSI themselves ("LEARNING") and/or (B) they support teachers in acquiring teaching skills to supporting their students in developing these competences ("TEACHING").

- **Relate your module** to (i) scientific competences, (ii) transversal skills like critical thinking, innovative mind-sets and forward-looking skills and (iii) taking into account the social, ethical and cultural aspects related to SSI when making decisions.

- **Provide explicit definition** of the learning outcomes expected in the prospective teachers taking part in the program (ESG, 2015). These learning outcomes should take into account the knowledge, values, dispositions and skills necessary for teaching environmental SSIs in science and mathematics.

- Develop and use **appropriate and responsive resources and strategies** to facilitate science and mathematics learning in diverse classrooms (with students diverse in relation to performance, socio-cultural background and cultural background, including ICT, the combination of multiple means and modes of communication, practical and collaborative activities and meaningful links to students' previous experiences and background (UNESCO, 2007, 2011, 2015; Zandvliet, 2012). Socio-Scientific Issues (SSI) are considered powerful scenarios to encourage communication and the consideration of multiple perspectives and thus a potential approach to enhance science learning in diverse classrooms. A module based on this topic should take into account current understanding on how to support teachers to use SSI to enhance science education, with consideration of cultural issues (Byrne et al., 2014; Christenson, & Chang, 2015; Gutierrez, 2015; Ideland et al., 2011; Morin et al., 2013; Paraskeva-Hadjichambi et al., 2015; Ratcliffe & Grace, 2003; Zeidler et al., 2013).

- The modules should include information to allow a **consistent evaluation of the learning outcomes** previously defined, by suggesting appropriate assessment criteria and methods.

- The content of the modules for teacher initial education should take into account the specialised research/literature in the field and successful projects/experiences focusing on the same/similar topics.

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Pedagogical approaches and methods

The following guidelines are intended at promoting the use of appropriate methods in the modules developed for teacher initial education:

- Ensure consistency between the explicit and implicit messages being delivered through teacher initial education.

- The methods used in Higher Education to prepare teachers for facilitating science and mathematics learning by including environmental SSIs should reflect and integrate those pedagogical approaches we want teachers to uptake in their future career. This recommendation is considered a basic principle for internal consistency in the implicit messages delivered through teacher initial education.

- For instance, using practical or experiential activities, multimedia resources and collaborative learning may be very helpful approaches for facilitating learning for diverse students. Therefore, the learning environments to be developed should include these kinds of activities for teacher initial education. For example, instead of lecturing, teacher educators may draw on introductory videos to make prospective teachers reflect on the specific challenges that could be encountered when dealing with SSI, and make teachers' students to discuss and negotiate meanings and solutions in a collaborative way.

- Include student centred pedagogies (ESG, 2015), such as Inquiry-Based Learning (IBL), Problem-Based Learning (PBL), collaborative work, outdoor pedagogy, hands-on and experiential activities based on current understanding on effective teaching and learning processes and successful teacher professional development.

- Include activities that make explicit teachers' beliefs and concerns and provide teacher educators with strategies to build on them.

- Enable flexibility and adaptability to different teacher students. This latter guideline refers to the use of methods that allow adaptation to different learning paces and teacher students' backgrounds, for instance, through the use of collaborative open-ended activities, which could be approached by teacher students in very different ways.

Resources, materials and environments

Along with guidelines for the quality of content and methods, the learning environments should be designed to promote free access, usability, adaptability and sustainability of the modules and

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resources being produced. The following guidelines provide support to address these issues. In this line we recommend:

- Using easily available and potentially contextualised resources. An example on how this recommendation may be met is by providing guidelines about how teacher educators can search for updated news from their own local context to prompt a particular debate in the classroom.

- Taking into account guidelines for the development and use of Open Educational Resources (UNESCO, 2015).

- Using computer-based resources to facilitate and enhance learning. An example may be the application of computer simulations to make visible the non-visible, represent abstract ideas or allow connections between different languages and modes of representation in science and maths (Ariza & Quesada, 2014).

- Drawing on principles about multimedia learning and specialised research on effective use of computer-based education (Ariza & Quesada, 2014; Mayer, 2002; Trouche et al., 2013; Zandvliet et al., 2012).

- Ensuring adaptability to different contexts and educational needs by using editable formats and publication under the Creative Commons license.

- When possible, taking into account the granularity principle. It refers to the development of independent meaningful learning objects with an optimum size, which could be easily combined in different ways, increasing versatility, adaptability and thus, usability of the modules and materials being produced.

- Providing resources with appropriate meta-data to facilitate the identification of materials and their use (target group, relevant topics, estimated time, key competences to be developed…).

- When possible, enrich the materials with information about previous experiences with them and illustrative case studies. This information will enhance the understanding of contextual factors, disseminate good practices and allow the potential adaptation to different contexts.
- Facilitating the integration into different virtual learning environments through the use of technical standards for interoperability and compatibility.

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Annex I provides a set of guiding questions based on the general guidelines presented above, that may be used for evaluating the quality of learning environments and reflecting on how to improve them.

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