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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Guidelines for Open Learning Environments

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.

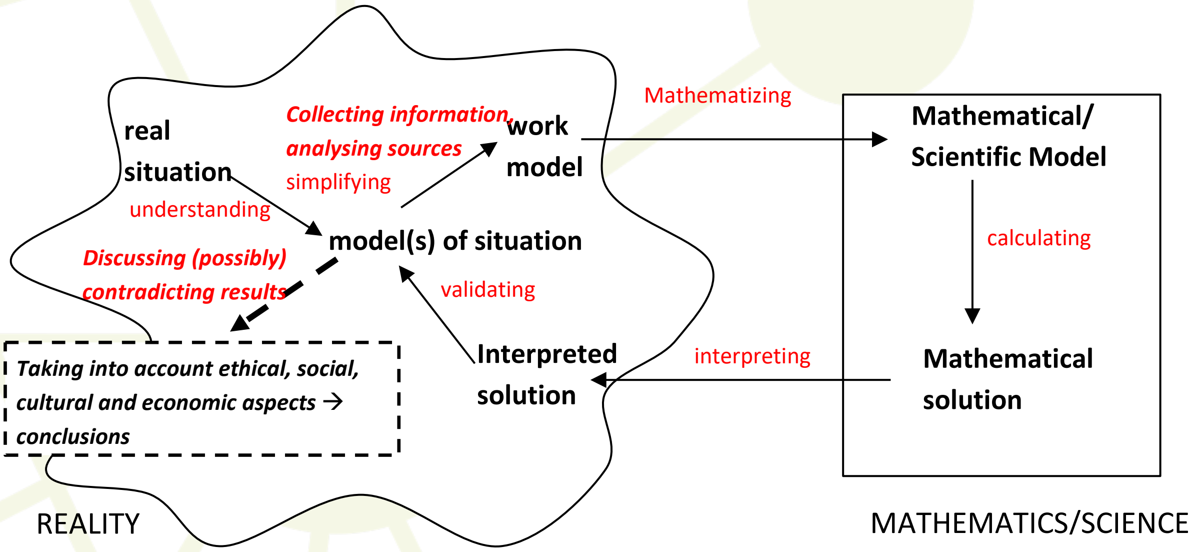

Fig. 3. Working process for socio-scientific issues (Maass, Doorman, Jonker and Wijers 2019)

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).

- **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 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.

References:

Applebaum, S., Barker, B., & Pinzino, D. (2006). Socioscientific issues as context for conceptual understanding of content. Paper presented at the National Association for Research in Science Teaching, San Francisco, CA.

Ariza, M.R. & Quesada, A. (2014). ICT and meaningful science learning. Enseñanza de las Ciencias, 32(1), 101-115.

Ariza, M.R., Quesada, A., & Abril, A.M. (2017). Enhancing Science and Mathematics Education in Multicultural Contexts: Guidelines for Open Learning Environments. In INTED2017 Proceedings 11th International Technology, Education and Development Conference (pp. 9458-9466). Valencia: IATED Academy.

Artigue, M., & Blomhøj, M. (2013). Conceptualising inquiry-based education in mathematics. ZDM Mathematics Education, 45(6), 797–810.

Askew, M., Brown, M., Rhodes, V., Johnsons, D., & Wiliam, D. (1997). Effective teachers of numeracy. London, UK: Kings College.

Byrne, J., Ideland, M., Malmberg, C., & Grace, M. (2014). Climate Change and Everyday Life: Repertoires children use to negotiate a socio-scientific issue. International Journal of Science Education, 36(9), 1491-1509.

Christenson, N., & Chang Rundgren, S. N. (2015). A Framework for Teachers' Assessment of Socio-scientific Argumentation: An example using the GMO issue. Journal of Biological Education, 49(2), 204-212.

Dewey, J. (1916). Democracy and education. New York, NY: Macmillan.

Dorier, J.-L., & Maass, K. (2014). Inquiry-based mathematics education. In Encyclopedia of Mathematics Education (pp. 300–304). Heidelberg, Germany: Springer.

Herman, B. Sadler, T., Zeidler, D. & Newton, M. (2018). A socioscientific issues approach to environmental education. In G. Reis, J. Scott, International perspectives on the theory and practice of environmental education: A reader(pp. 145–161). DOI: 10.1007/978-3-319-67732-3_11

Geiger, V., Goos, M., & Forgasz, H. (2015). A rich interpretation of numeracy for the 21st century: a survey of the state of the field. ZDM Mathematics Education, 47(4), 531–548.

Gutierrez, S. B. (2015). Integrating Socio-Scientific Issues to Enhance the Bioethical Decision-Making Skills of High School Students. International Education Studies, 8(1), 142.

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Ideland, M., Malmberg, C., & Winberg, M. (2011). Culturally equipped for socio- scientific issues? A comparative study on how teachers and students in mono-and multiethnic schools handle work with complex issues. International Journal of Science Education, 33(13), 1835-1859.

Knippels, M.C.P.J. & van Dam, F.W. (2017). PARRISE, Promoting attainment of responsible research and innovation in science education, FP7—Rethinking science, rethinking education. Impact, 2017(5), 52–54.

Maass, K., Doorman, M., Jonker, V. & Wijers, M. (2019). Promoting active citizenship in mathematics teaching. *ZDM Mathematics Education*, 51(6), 991-1003. DOI 10.1007/s11858-019-01048-6.

Mayer, R. E. (2002). Cognitive theory and the design of multimedia instruction: an example of the two-way street between cognition and instruction. New directions for teaching and learning, 89, 55-71.

Morin, O., Tytler, R., Barraza, L., Simonneaux, L., & Simonneaux, J. (2013). Cross cultural exchange to support reasoning about socio-scientific sustainability issues. Teaching Science, 59(1), 16.

OECD (2009). Creating Effective Teaching and Learning Environments. First Results from TALIS. Paris: OECD Publications http://www.oecd.org/dataoecd/17/51/43023606.pdf

OECD (2011) Preparing Teachers and Developing School Leaders for 21st Century - Lessons from around the world (Background Report for the International Summit on the Teaching Profession).

Paraskeva-Hadjichambi, D., Hadjichambis, A. C., & Korfiatis, K. (2015). How Students' Values Are Intertwined with Decisions in a Socio-Scientific Issue. International Journal of Environmental and Science Education, 10(3), 493-513.

Osborne, J.F., & Dillon, J. (2008). Science Education in Europe: Critical Reflections. London: The Nuffield Foundation.

Owen, R., MacNaghten, P., & Stilgoe, J. (2009). Responsible research and innovation: From science in society to science for society, with society. Science and Public Policy, 39, 751–760

Radford, L. (2010). The anthropological turn in mathematics education and its implication on the meaning of mathematical activity and classroom practice. Acta Didactica Universitatis Comenianae Mathematics, 10, 103–120.

Radakovic, N. (2015) “People can go against the government”: Risk-based decision making and high school students’ concepts of society. Canadian Journal of Science, Mathematics and Technology Education, 15(3), 276–288, DOI: 10.1080/14926156.2015.1062938

Ratcliffe, M., & Grace, M. (2003). Science education for citizenship: Teaching socio- scientific issues. McGraw-Hill Education (UK).

Sadler, T. D., Barab, S. A., & Scott, B. (2007). What do students gain by engaging in socioscientific inquiry? Research in Science Education, 37(4), 371–391. DOI: 10.1007/s11165-006-9030-9

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Swan, M. (2005). Improving learning in mathematics: Challenges and strategies. Sheffield, UK: Teaching and Learning Division, Department for Education and Skills Standards Unit.

Swan, M. (2006). Collaborative learning in mathematics: A challenge to our beliefs and practices. London, UK: National Institute for Advanced and Continuing Education (NIACE) for the National Research and Development Centre for Adult Literacy and Numeracy (NRDC).

Swan, M. (2007). The impact of task-based professional development on teachers' practices and beliefs: A design research study. Journal of Mathematics Teacher Education, 10(4–6), 217–237.

Trouche, L., Drijvers, P., Gueudet, G., & Sacristan, A. I. (2013). Technology-driven developments and policy implications for mathematics education. In Third international handbook of mathematics education (pp. 753-789). New York: Springer.

UNESCO (2007). Unesco Guidelines on Intercultural Education. Paris: UNESCO.

UNESCO (2011). Unesco ICT Competency Framework for Teachers. Paris: UNESCO.

UNESCO (2015). Guidelines for Open Educational Resources (OER) in Higher Education. Paris: UNESCO.

Walker, K. A. (2003). Students' understanding of the nature of science and their reasoning on socioscientific issues: A web-based learning inquiry. Unpublished dissertation. Tampa, FL: University of South Florida.

Zandvliet, D. B. (2012). ICT learning environments and science education: Perception to practice. In B.J. Fraser, K. Tobin & C. J. McRobbie (Eds.), Second International Handbook of Science Education (pp. 1277-1289). New York: Springer.

Zeidler, D. L., Herman, B. C., Ruzek, M., Linder, A., & Lin, S. S. (2013). Cross-cultural epistemological orientations to socio-scientific issues. Journal of Research in Science Teaching, 50(3), 251-283.

Zeidler, D.L., & Nichols, B.H. (2009). Socio-scientific issues: Theory and practice. Journal of Elementary Science Education, 21(2), 49–58.

Zohar, A., & Nemet, F. (2002). Fostering students' knowledge and argumentation skills through dilemmas in human genetics. Journal of Research in Science Teaching, 39, 35–62.

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Annex I. Guiding questions for the quality evaluation of learning environments

Based on the general guidelines for the design of high quality learning environments, the following questions can be used to guide the evaluation and improvement of the modules.

Key aspect to be evaluated	Guiding questions	Do you have any concrete suggestion to improve this aspect?
Adaptation to the target group	Are the activities appropriate for the target group (adapted to their capacities, needs and interests)?	
Relevancy	Are the topics and themes being developed important to build teachers' capacity to deal with environmental SSIs and to support students in developing these competences? Is the content appropriate and relevant to work on the selected topic[1]? Do you miss any relevant aspect/content to develop the selected topic[1]?	
Learning outcomes	Does the module include the definition of consistent learning outcomes in terms of the competences to be achieved by teachers through engaging in the activities?	

[1] Examples of selected topics are socio-scientific issues, language in mathematics education, etc.

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Key aspect to be evaluated	Guiding questions	Do you have any concrete suggestion to improve this aspect?
Assessment	Does the module include assessment criteria, instruments or procedures that allow teacher educators to evaluate to what extent participants have achieved the learning outcomes previously defined?	
Foundation	Does the module include references to back up the design of the module or the activities being proposed? Does the module include interesting or useful literature references or links to previous successful experiences in the field?	
Pedagogy	Are teachers encouraged to express their beliefs and concerns in order to build on them? Are the examples, activities and tasks appropriate and relevant for working on the selected topic[1]?	
Learners' centred pedagogy	Do the activities offer pre-service teachers the opportunity to play an active role in their own training process (collaborating, discussing, reflecting, building, designing, enacting…)?	
Usability	Can the activities and resources proposed be easily implemented in daily practice? Is the power point presentation well-structured and easily understood?	

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Flexibility	Does the module encompass activities and resources that can be easily modified and adapted to different contexts?
Granularity	Does the module encompass a wide range of short activities that can be flexibly used and combined to adapt to different needs and context?
Open Education Resources	Does the module include Open Educational Resources (OER)? OER are open access resources that frequently are computer-based materials that can be edited and modified to adapt to different users?
Technology	Does the module make an effective used of media and current technological resources (videos, simulations, social networks, wikis, forums…)?
Metadata	Does the module provide appropriate meta-data to allow potential users to identify and select the resources according to their needs and interests?
Contextual information and illustrative cases	Does the module include information about previous experiences related to the implementation of the activities and resources being described (contextual information, case studies…illustrative best practices…)?

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