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A Professional Development session on Environmental socio-scientific issues and its impact on Prospective mathematics teachers' task designs

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TOPIC 1, Proposal for Oral presentation

Abstract This study explores one teacher educator's actions while enacting a professional development session on environmental socio-scientific issues for prospective mathematics teachers in the context of a European project. The focus is also on the extent that this session could support the participating prospective mathematics teachers' exploitation of these issues. We analysed the teacher educator's actions and resources as well as the prospective teachers' task designs with respect to their authentic, social and controversial characteristics, and the modelling steps required to be carried out for their enactment. The results indicate that supporting sustainable education for prospective mathematics teachers is feasible.

Keywords Environmental socio-scientific issues; Prospective mathematics teachers' task designs; Teacher educator's actions

1. Introduction

The literature review suggests that there is a need for developing a Professional Development (PD) model to prepare European prospective mathematics and science teachers to integrate Environmental socio-scientific issues (EnvSSIs) in science and mathematics classrooms (Maass et al. 2019). It seems that this integration is challenging for mathematics teachers, primarily due to their ill-preparedness in leading debates on such topics and the perception that mathematics is a politically-neutral and context-free domain of knowledge (Barwell et al., 2022; Evagorou, 2011; Owens et al., 2019). Thus, exploring ways of enacting a PD session addressed to prospective mathematics teachers (PMTs), in order to support them in designing tasks relevant to EnvSSIs; and the impact of this session on PMTs' designs could be of interest in the field.

The present study took place in the context of a European Project (ENSITE, https://ensite-project.eu/) aiming to enrich prospective teachers' competences for designing and implementing EnvSSIs in mathematics and science classrooms. In the context of this project, several modules were designed and piloted in many European Universities.Particularly, four Greek teacher educators (TEs) designed and enacted short Professional Development (PD)

sessions to support prospective mathematics and science teachers to include in their teaching practices tasks on EnvSSIs. This paper reports on one of these cases.

This study explores a TE's actions while enacting a teaching session on EnvSSIs for Postgraduate Mathematics Teachers (PMTs) and the extent that this session could support PMTs' exploitation of these issues. The research questions are:

RQ1: What are the TE's actions aiming to support PMTs to teach EnvSSIs in mathematics classrooms?

RQ2: What is the impact of TE's actions on PMTs' exploitation of EnvSSIs in their task designs?

2. Literature review

Hauge and Barwell (2022) propose the following two principles for designing PD courses to support mathematics teachers to teach EnvSSIs: a) exploring meaningful situations of risk and uncertainty and b) incorporating both scientific/mathematical concepts and societal perspectives. Furthermore, linking environmental issues with task authenticity is evident in many studies. Specifically, the environmental issues seem to possess the following essential authentic task characteristics: a) the out-of-school origin and b) the certification of originality, so that to engage students in authentic, meaningful, and context-driven mathematical modelling processes addressing societal concerns (Yaro et al, 2020). Thus, the modelling cycle has been recently extended to include modelling steps relevant to citizenship education (Maass et al., 2023).

3. Context and Methodology

The PD session we study here was part of the undergraduate course entitled 'Teaching through Problem solving-Mathematization' based mostly on parts of the modules developed in the ENSITE project and lasted for 7 teaching hours. In the course's final assignment, 47 PMTs (working in groups of 2-3) were asked to design a mathematical problem that concerns an environmental issue of their choice; present the relevant socio-scientific issue; and provide the sources used in their design. PMTs designed 22 tasks.

The data for this study are a) the TE's lectures and teaching material and b) PMT's task designs. The TE's lectures were analysed in terms of her teaching actions and goals. The analysis of PMTs' task designs and the resources the TE used in the PD session was carried out in two phases. In the first phase, all materials were analyzed by focusing on four dimensions: a) their authenticity; b) the emphasis given on the societal and the c) controversial aspects of the problem; and d) the identification and further use of mathematical modelling steps needed for enacting the specific tasks as described by Maass et al. (2023, p. 138). These steps include: understanding the task (step 1); collecting information, analyzing sources (step 2); mathematizing (step 3); using mathematics (step 4); interpreting the mathematical solution (step 5); validating the mathematical solution (step 6); discussing contradicting results (step 7); and decision making by considering ethical, social, cultural and economic aspects (step 8). In the second phase, we selected three exemplary TEs' resources and five PMTs' task designs to illustrate the existence or not existence of the above dimensions.

4. Results

4.1 TE's actions enacting the PD session.

a) Inviting four PMTs who participated in an online ENSITE Multiplier event to introduce EnvSSIs to their classmates. The goal of this action was to familiarize PMTs with EnvSSIs and their controversial side.

b) Suggesting and discussing specific Environmental tasks that could be used in mathematical classrooms. These tasks were developed in the ENSITE project. Some of these tasks were the *Climate change*, the *Ecological footprint*, and the *Lake drainage* tasks. The goal of this action was to specify the mathematical modelling processes involved in these tasks. The presentation of the tasks was mostly based on steps 1 (introducing PMTs' to the specific environmental issue), then by providing pre-defined mathematical models and mathematical solutions, the PMTs had to move to steps 5 (interpreting the mathematical models), step 7 (discussing possible contradicting results) and step 8 (decision making based on ethical/social/cultural aspects). For example, in the *Ecological footprint*, graphs based on authentic resources from three different countries were given. These graphs show the bio-capacity evolution from 1961 to 2016 in the specific country. PMTs had firstly to understand the meaning and importance of the ecological sustainability of a specific area as well as the relation between the area's bio-capacity and the ecological footprint of humans living in this area (step 1). Then, PMTs were requested to study, interpret and compare the data on the graphs (step 5) and suggest ways to decrease the ecological footprint of a country and to deal with the problem of ecological deficit and physical unsustainability that this country may face (Step 8).

c) Implementing an online survey quiz with the question: "Paper or plastic bags, which is better for the environment?". In this activity, PMTs had to read several resources and provide an argument for the one or the other choice. Subsequently, PMTs were asked to analyse their classmates' arguments by using the Toulmin's framework. The goal of this action was to support PMTs' evaluation of arguments.

d) Using a digital calculation tool to engage PMTs in counting their ecological footprint with the goal to sensitize them on relative issues.

Thus, TE emphasised on the controversial characteristics of EnvSSIs (Actions a, c); raised PMTs' sensitivity to such issues (Actions a, d); and supported students to acknowledge the mathematical aspect of these issues (Action b). On the other side, TE provided examples based on pre-defined mathematical models while no validation was needed for these models.

4.2 PMTs' exploitation of EnvSSIs in their task designs.

Among a number of PMTs' interesting answers, five proposed assignments indicate PMTs' exploitation of EnvSSIs.

(a) The *Fire fighting* task*:* the students had to develop ways to prevent forest fire-fighting, explore the main causes and make the better choice of trees for reforestation.

(b) The *Railway* task: the students had to decide on /the expropriation of a piece of land to benefit from a new railway track.

(c) The *Fashion Ecological Footprint* task: the students had to explore ways to lower the ecological footprint from clothing production.

(d) The *Sinking Village* task: develop ways to rescue a sinking village in Indonesia.

(e) The *Donation* task: choose the best way to recycle plastic for making a donation to a disabled person.

Some extracts from PMTs' tasks are: 'Study the energy consumption of trains versus cars and state the benefits from each choice' (*Railway*); 'where would you put the factory, if you wanted the least CO_2 emission and the lowest production cost?' (*Fashion Ecological Footprint*); *'*Argue on the following question: Pine tree: just a beautiful tree or real bomb*?'*(*Fire fighting*); 'Save the village of Timbulsloko by creating a protection zone planting bamboo or mangroves trees. Which is the best choice*?'* (*Sinking Vvillage*).

As regards the modelling steps for solving the corresponding problems, all tasks aimed to introduce students to the environmental problem (step 1) and take into account their controversial aspects (step 7). For example, the negotiation in terms of profit and cost was present in *Sinking village*, *Railway* and *Fashion ecological footprint*. In two tasks, students had to interpret pre-defined mathematical models (step 5). For example, in *Firefighting* students

had to use statistical measures to interpret the models given and discuss the best ways of reforestation and firefighting means. In three tasks, students had to construct mathematical models (step 3) and the mathematical solutions (step 4) based on the given information. For example, in the *Railway* students had to develop the arithmetical progression of the CO_2 emissions amount per year. Only the *Sinking village* can be considered as 'holistic modelling task' (Maass et al., 2023, p. 141) as it required by students to carry out almost all modelling steps. Specifically, students were asked to collect information from given resources (step 2), develop specific mathematical models (step 3), calculate the area and the cost of planting the trees (step 4), interpret the results and argue on different type of trees to be used (steps 5, 7) and make choices taking into consideration specific social and cultural aspects such as the urgency to save the cemetery. In none of the PMTs' task designs students were asked to validate their mathematical results (step 6).

The societal aspect was also ascertained in all the above tasks. We can list for example, the reference to a recent and catastrophic Greek fire that caused many people deaths (*Firefighting*); the priority of rescuing a cemetery (*Sinking Village*); the promotion of the value of volunteering (*Donation*); and the sensitivity to global self-awareness about the planet climate change (*Fashion Ecological Footprint*).

Finally, all of the above tasks maintained original and authentic characteristics since they were different from these that the TE presented in her lectures and they were based on authentic resources such as: national data (*Firefighting*, *Fashion ecological footprint*, *The sinking village*); online articles, newspapers and magazines (*Firefighting*, *Donation*, *Sinking village*);sites about environmental issues https://adoptabeach.wwf.gr/schools (*Donation*), https://climate.nasa.gov/vital-signs/sea-level/ (Si*nking village*); world Resources Institute: https://www.wri.org (*Fashion ecological footprint*); andresearch papers (*Firefighting, Sinking village, Fashion ecological footprint*).

5. Conclusion

This study provides an example of introducing global realities to PMTs through the design of a short PD session based mostly on high quality and ready-to-use materials that were developed in the context of the European Project ENSITE.

The TE emphasized on the controversial and the societal characteristics of EnvSSIs and she tried to raise PMTs' sensitivity to such issues. The above characteristics were also identified in the five illustrative examples of PMTs' task designs. Even though the TE used examples with pre-defined mathematical models, the PMTs attempted to design tasks that could include the development of mathematical models. Validation of the mathematical models and solutions was absent in TEs' teaching materials as well as in PMTs' task designs.

Thus, TE needs to develop more or different actions to stand up for her students to learn how to integrate all the modelling steps of the extended modelling cycle into their designs. The inclusion of holistic modelling tasks in mathematics teaching could support students to relate mathematics with issues relevant for society (Maass et al., 2023). The originality and the authenticity of PMTs' task designs show the potentiality of related mathematics teaching with EnvSSIs. The supporting elements in this direction are the careful design of PD sessions and the high-quality and ready-to-use materials developed in the ENSITE project.

This study suggests that if these short PD sessions become functional parts of specific undergraduate courses in the upcoming years it could be the start of supporting sustainable education in respect to EnvSSIs for prospective mathematics teachers (Maass et al., 2019).

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