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A teaching session on environmental socio-scientific issues for prospective mathematics teachers: Teacher educators' actions and challenges

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This study explores a mathematics teacher educator's activity during an undergraduate course about problem solving by incorporating a session on environmental socio-scientific issues. The data came from the audio taped teaching session and an interview with the teacher educator. We view the teacher educator's activity through the lens of Activity Theory. The aim of this activity is to support prospective mathematics teachers to design and enact tasks relevant to such issues in mathematics classrooms. Our analysis reveals that the teacher educator adopted a pattern of four actions to convince prospective mathematics teachers of the significance of including tasks related to environmental issue in their teaching. Analysis also shows the challenges the teacher educator had to deal with in order to fulfill the object of the activity.

Keywords: Environmental issues, prospective mathematics teachers, teacher educator's activity.

Introduction

Contentious environmental issues are often considered as socio-scientific issues (e.g., climate change) since they are rooted in mathematics and science and include many non-scientific dimensions (e.g., cultural, political, economic, etc.). Teachers, especially mathematics teachers, often report being ill-equipped to address socio-scientific issues in their classrooms primarily because they have to deal with the uncertainty involved in them (Owens et al., 2019). Recently in mathematics education, many researchers have admitted that the global environmental crisis (e.g., global warming, acid rain etc.) challenges mathematics educators' values and ethics. These researchers came to this conclusion after posing one central retrospective question to the mathematics education research community: "What is the role of mathematics education in the global environmental crisis?" (Boylan & Coles, 2017, p.2). Ideological responses to this question have been extensively addressed in contemporary literature (Boylan, 2016; Boylan & Coles, 2017). However, only a limited number of studies have focused on how mathematics teachers could be supported to enact these issues in their classrooms (Maass et al., 2019). Thus, there is limited knowledge on how teacher educators (TEs) develop a teaching session for mathematics teachers under the goal of supporting them in including environmental socio-scientific issues (EnvSSIs) in their teaching actions. Our study explores how one TE developed a teaching session for prospective mathematics teachers (PMTs), analyzes aspects of the TE's teaching choices, discusses what constraints this TE met, and how they dealt with these challenges. Our research questions are RQ1: What patterns of actions do we recognize in the TE's teaching activity? RQ2: What challenges did the TE meet in this activity?

Theoretical Perspective

Literature review

There is increasing interest within the mathematics education community on TEs' actions when implementing a professional development (PD) course because: the TE role is crucial for strengthening teachers' professional expertise (e.g., Büscher & Prediger, 2022; Karsenty et al., 2021). A specific context of teachers' professional expertise is on how to promote students' environmental awareness. Some researchers have proposed the context of mathematical modeling for integrating environmental issues with mathematics teaching (Gürbüz & Çalik, 2021). Other researchers have argued against this perspective (Mikulan & Sinclair, 2017). In order to support mathematics teachers to deal with the uncertain dimensions related to EnvSSIs, Hauge and Barwell (2022) proposed three principles for designing PD courses. These are: exploring meaningful situations of risk and uncertainty; exploring both scientific/mathematical concepts and societal perspectives; and exploring and learning through dialogue. Maass et al. (2019) presented an interdisciplinary approach in which teaching and PD materials were developed in order to connect mathematics and science education to citizenship education. They suggested that when dealing with EnvSSIs, the modeling process needs to be extended to fully take into account the specific features of such issues. These extensions could include search for information and (risk) analysis of sources of information, discourse about (possibly) contradicting scientific results and ethical, social, cultural reasoning.

Activity theory as our theoretical and analytical tool

We view TEs' activity through the lens of activity theory and draw evidence from data generated within a teaching session related to problem-solving and EnvSSIs. Activity theory as our theoretical and analytical tool presents Engeström's (1998) view of an activity system represented by a triangle. The triangle links relations between mediational means (tools and materials), the subjects, and the object of the activity with elements of the activity's relevant communities. In particular, the framework allows us to map out relations between the subject and the object of the activity that are constructed through the mediation of tools, the community in which the subject participates, and its rules and the division of labor. In our study, the activity is a short PD session. This session is a part of an undergraduate course in a mathematics department, in Greece. The object of the TE's activity is to inform PMTs about the need to design and enact tasks relevant to EnvSSIs in a mathematics classroom. The activity system subject is the TE whose actions and goals we studied. We view the TE's activity oriented towards the aforementioned object while the TE's actions are conscious processes directed at goals which must be undertaken to fulfill this object of the activity (Roth & Radford, 2011). Tools are all the materials the TE has designed or chosen. These materials are examples of environmental tasks and the socio-scientific issues related with them. Most of these materials were developed in the context of the European project ENSITE (<https://icse.eu/ensite/>). The TE is a mathematics department staff member. The community rules are the outline of the undergraduate course the TE taught, while division of labor was the TE's responsibility to design their course lectures and evaluate PMTs' work.

Context and methods

The ENSITE aimed to enrich prospective mathematics and science teachers' competences for designing and implementing EnvSSIs in their classrooms. In ENSITE, several modules were designed and piloted in many European universities. In this context, four Greek TEs designed and enacted short

PD sessions to support PMTs to include tasks on EnvSSIs in their teaching practices. This paper reports on one of these cases. The PD session we study here was part of the undergraduate course entitled *Teaching through problem solving-mathematization*. The course purpose is to inform PMTs on topics concerning problem solving and mathematical modeling, and on current research issues in this field. This course further aimed to: support PMTs in posing mathematical problems based on given, real-world situations; develop their problem-solving skills; and organize and orchestrate classroom discussions. This context provided a fertile setting for enacting an EnvSSIs focused PD session that consisted of 10 teaching hours. The tasks used were developed either in the ENSITE project (i.e., examples 2 and 3), or taken from the new Greek curriculum (example 1). All tasks were adopted according to the course aims and purposes.

Data analysis process

The data for this study are the audiotaped 10-hour teaching session, the materials the TE used, and an interview with the TE. Firstly, we audiotaped and then transcribed the PD session. In a second step, we divided the teaching session into episodes according to the EnvSSIs presentation and discussion. In each episode, we identified the TE’s actions, goals, and prompts enacting these tasks in their lectures. Thirdly, we located a pattern of actions (consciously or unconsciously) that was repeated in each episode. From here, we designed an interview with the TE to explore how they made their teaching choices. Characteristic questions were: “Can you explain your main goals for this session?” “Why do you think is important to support PMTs in teaching environmental issues?” “What were the main challenges you met and how did you handle them?” In the last phase, we specified the goals in the TE’s main teaching actions, identified the challenges this TE faced. Finally, we connected this data with activity system components.

Results

Teacher educator’s patterns of actions (RQ1)

There were patterns of TE’s actions while trying to support PMTs’ in realizing the importance of using EnvSSIs-based problems in their future mathematics classrooms. Table 1 represents the main patterns of actions the TE adopted throughout the teaching session, the goals of the specific actions, and the characteristic TE prompts.

Table 1: Presentation of teacher educator’s patterns of actions

TE’s Actions	Actions	Goals	Characteristic TE’s questions/prompts
Action 1	Introducing a specific EnvSSI and discuss with the PMTs the significance of the issue selected.	Familiarize PMTs with the context of the specific EnvSSIs	What do you know about this issue? What is your opinion? Is it a global or a local issue?
Action 2	Suggest a problem related to the issue (Action 1) and ask the PMTs to provide possible solutions of the problem.	Identify the mathematical dimensions of the problem	Try to solve the problem; what mathematics do you recognize in this problem? In which grade could you teach this problem? Do you see possible differences between this task and the other mathematical school tasks?

Action 3	Ask PMTs to identify the social aspect of the specific problem (Action 2); discuss conflicting views	Connect the social with the scientific dimensions of the specific task	Which scientific field is involved here? Can you see pros and cons while adopting a specific aspect of this environmental issue?
Action 4	Ask the PMTs to provide ideas on how to enact this problem in the classroom by taking into consideration the discussion in Actions 1-3	Engage PMTs in the role of the teacher and think about the challenges they encounter while enacting this task	How can you deal with it in the classroom? What resources could you suggest to students?

It seems that each of the above actions were directed by content-focused goals while the forming of a repeated pattern of actions was directed (implicitly or explicitly) by process-focused goals (Karsenty et al., 2021). Below we present three examples of EnvSSIs and TE's patterns of actions while enacting them in lectures.

Example 1: The wind turbines environmental issue

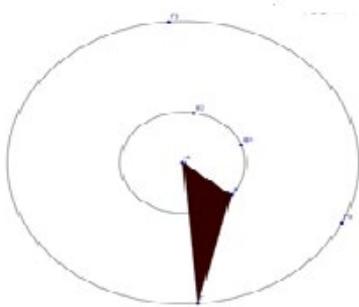


Figure 1: The windmill blade

Action 1: Introducing the environmental issue on wind turbines. TE's prompts were: "In what way do windmills differ from wind turbines? What issues are raised in society about using wind turbines? What are the pros and cons of using wind turbines?"

Action 2: Suggesting to PMTs a specific problem: *'Design a windmill blade: Design a windmill blade as in the figure (Figure 1). TE asks PMTs to suggest ways of orally presenting possible solutions: "How do you solve this task? What mathematical concepts and/or geometric concepts are involved here?"*

Action 3: TE discussing the necessity to move from windmills to wind turbines; asking PMTs to express contrasting opinions about the installation of wind turbines in an area to produce electricity from renewable sources; distinguish the pros and cons of using wind turbines in the local environment and the sustainable development of an area; utilize and interpret bibliographic data and information about energy production from wind turbines.

Action 4: Asking PMTs to provide ideas on how to enact the task in Action 2 in mathematics classrooms "How could you deal with it in the classroom? How would you support the uncertainty of this issue?" The TE insists that in such issues there is no right or wrong answer. The evaluation of students' responses could be analyzed in terms of argumentation theory approaches, such as the Toulmin model.

Example 2: The drainage and the re-flooding of Lake Karla, Thessaly, Greece

Action 1: Introducing the history of Lake Karla and informing students about some details and original data from the drainage and restoration of Lake Karla. Characteristic TE's prompts: "Why did the government make these decisions? What possible environmental issues are related to the drainage of Lake Karla?"

Action 2: TE provides PMTs with the following two diagrams (Figures 2, 3) and asks PMTs to interpret and connect the information presented in the two diagrams:

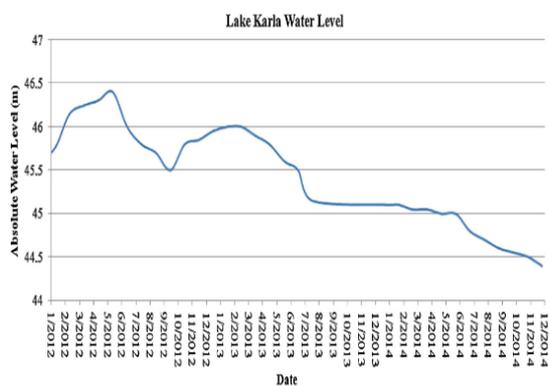


Figure 2: Lake Karla water level from 01/2012- 12/2014

Figure 3: The relation between the water level and the salinity of a lake

Some characteristic TE’s prompts are: “What do you see in these diagrams? In Figure 2, it seems that the water level of the Lake Karla appears to decrease, can you provide some reasons? What is the allowable salinity level to sustain life in the lake (Figure 3)? Can you compare the given data and draw conclusions? What kind of mathematical knowledge does the interpretation of these diagrams require? Are there other scientific fields involved while interpreting these diagrams?”

Action 3: TE assists PMTs in identifying the social aspects of the re-flooding of the Lake. Characteristic prompts: “It seems that they drained the lake and later decided to refill it, why? What environmental issues do you recognize here? What benefits will there be from the re-flooding of Lake Karla?”

Action 4: Asking PMTs to provide ideas on how to enact this issue in the classroom: “Would you give the above diagrams to your students? Why? Why not? What would students benefit from this task?”

Example 3: The lake pollution task

Action 1: TE presents a textbook task (Figure 4) on a mathematical model that describes the pollution of a lake. The task presents a function $f(t)$ that describes the lake’s oxygen content (%) in t days after waste had been dumped in the lake. TE asks PMTs: “What kind of environmental issues do we have here? Are these issues transparent in the task presentation?”

Action 2: Some TE’s prompts: “Can you solve the textbook task?”

Action 3: TE discusses the environmental aspect of the problem and extends it to social dimensions: “It seems that after 20 days everything returns to ‘normal.’ Does the oxygen decrease affect fish and organisms in the lake? What are the environmental impacts? How could you change this textbook task in order to make the socio-scientific dimensions of this task evident?”

Action 4: The TE asks PMTs to look for other textbook tasks that relate in some way to environmental issues and make proper task transformations in order to do transparent their socio-scientific dimensions.

- When organic waste is thrown into a lake, the oxidative process, that is created, reduces the oxygen content of the lake.
- Suppose that the following function describes the oxygen content (%) of the normal level at t days after waste has been dumped into it.

$$f(t) = 100 \frac{t^2 + 10t + 100}{t^2 + 20t + 100}$$

- Q1) What is the oxygen content in the lake after 10 and 20 days;
- Q2) Calculate the $\lim_{t \rightarrow +\infty} f(t)$ and explain the result.

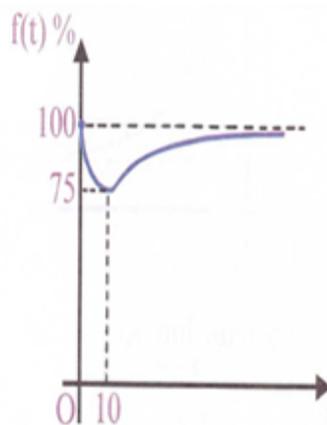


Figure 4: The lake pollution textbook task, translation from a Greek Grade 12 textbook

Teacher educator's challenges (RQ2)

Our data analysis indicated that the TE faced challenges during this PD session. It seems that these TE's challenges come from the norms in their school and academic communities, and from PMTs' personal beliefs about mathematics as an abstract, value-free field of knowledge (Bishop, 2008). Moreover, many PMTs seemingly believed there are other school subjects more appropriate than mathematics to support students being aware of such issues. (TE: Teacher Educator, R: Researcher)

TE: Some of them [PMTs], before starting to talk about environmental issues, were negative even on dealing with real-world problems... one student said to me on the first day of the course: "I study in this mathematics department; I am not interested in knowing the relation of mathematics with real-world situations."

R: It seems that the question, on the necessity of using this type of task in mathematics classrooms, keeps coming back from the PMTs. For example, different students wonder: "Why do we have to do all this?" "What will [school] students gain in mathematics?" I think that you avoided responding to these PMTs comments directly. Why?

TE: I chose not to respond directly to their concerns and doubts. I preferred to continue presenting specific examples of mathematic tasks related to environmental issues and let them reflect on how they might introduce them in their classrooms. At the end of this session, I devoted two hours on discussing their doubts and concerns, and helping them realize their role as mathematics educators.

Another challenge the TE faced was PMTs' academic experiences due to the theoretical orientation of the department: "Their academic experiences in this department do not support them. For example, in none of their statistics courses have they done 'big data analysis' as this department has a clear theoretical direction even for applied courses like statistics." The TE also commented on the factors which were supportive in the design and enactment of the specific PD session. They acknowledged that the involvement in the ENSITE project had provided needed tools and resources. "I might not have been able to start the session if I had not been involved in this project. It is very important to have some teaching materials ready to use." The PD session was very supportive as well: "The context of this course, problem solving and modeling authentic situations, is the perfect context to introduce these tasks."

Conclusions

This study provides an example of how a teacher educator introduced global realities to perspective mathematics teachers through a short professional development session as part of an undergraduate course on problem solving in a mathematics department. The TE used a pattern of four actions that appeared repeatedly during the session. The TE follows this pattern of actions in order to support the tasks' mathematical and social dimensions. Moreover, the TE had to align their content-focused and process-focused goals with the community rules, as this TE is an academic member of a theoretical-oriented mathematical department. Patterns of the TE's actions could also be indications of own prioritizations and beliefs about students' learning processes (Büscher & Prediger, 2022). The main challenge the TE faced was persuading PMTs about the necessity of enacting these issues in mathematics classrooms. Community rules (theoretical academic PMTs' experiences) and PMTs' epistemological beliefs about the nature of mathematics added to TEs' faced challenges. The literature also reports on the epistemological differences between mathematics and other STEM subjects that usually deal with EnvSSIs and beliefs about mathematics as a value-free subject (Bishop, 2008; Triantafyllou et al., 2021). Besides the above, there are supportive elements that encouraged the TE to enact this PD session. These are a) the PD resources which are mostly based on high quality and ready-to-use materials developed in the context of the European project ENSITE and b) the view of environmental issues as authentic, meaningful, and context-driven mathematics tasks that address issues of societal concerns (Yaro et al., 2020). Our study provides new insights on the sources of TEs' challenges and on the supportive elements that can guide teaching actions that aim to convince PMTs about the significance of including EnvSSIs in their teaching. We also demonstrate challenging tasks that could engage students in a rich and meaningful mathematical activity. This activity includes interpreting scientific resources and transforming from context-free to context-specific mathematical textbook tasks.

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