Abstract

The paper presents an example of implementation an inquiry-based learning (IBL) and teaching reflective practice or professional competence development of teachers in science, technology, engineering and mathematics (STEM). The educational scenario “Open air lessons – myth or not...” follows the template, developed under the Enhancing Learning in Teaching via e-inquiries teaching and learning (Erasmus+) project, for STEM teachers professional competence development. The teachers’ educational methodology steps on the Working Environment with Social and Personal Open Tools (weSPOT) project IBL model.

The teachers training aims to achieve two goals. At one hand, as a direct goal, the teachers to develop their skills for design, logistics and delivery of open air holistic lesson, applying different innovative methods and tools for assessment learners’ achievements and for evaluation of setting and process of this educational process. At other hand, in parallel they are developed the teachers’ researchers’ competences, communication and problem solving skills, and their critical thinking.

The article represents the educational scenario and its pilot implementation as a meta-course for STEM teachers and teachers’ educators. The pilot implementation takes place on open air at „Cedar“ cottage campus (the name of the campus relates to the task assigned to participants). The trainees are engaged in innovative educational practices – games, puzzle solving, solving problems, creative assignment, field study, literature research, and teamwork. The research approaches, used by participants are describes, as well as the results of their application. Analysis of the value of teamwork and reflective practice is provided.

It is presented the trainees’ feedback and their ideas for transferability the experience, gained during the meta-course, to their own classrooms.

Keywords: Inquiry-based learning, teachers’ professional competences development, STEM teachers’ training.

1 INTRODUCTION

Science, Technology, Engineering and Mathematics (STEM) education has a key role in contemporary economic growth. According to resent reports by the Organisation for Economic Co-operation and Development (OECD) only innovation-driven growth has a potential to create value-added jobs and industries [1]. An in-depth research by Corlu, Capraro & Capraro shows that innovation is largely derived from advances in STEM and an increasing number of jobs at all levels require STEM knowledge. As innovation involves the integration of diverse STEM competences and transcends disciplines, and it is a highly interactive and multidisciplinary process tightly connected to life, the importance of STEM education increases dramatically for today’s economics and life.

Teaching in the 21st century is more than a task confined in classroom frames and it demands more than the acquisition of content, pedagogical knowledge and technical skills. Teachers nowadays need the competence to innovate and adapt to opportunities emerging from the new digital era. This includes having critical, evidence-based attitudes to available resources, enabling them to respond to student outcomes, evaluating new evidence from inside and outside classrooms, and engaging in professional dialogue, in order to adapt their own practice for better students’ learning outcomes [2] (European Commission., 2013). Teachers, therefore, need to be supported in their new role as reflective practitioners, responsible for their own learning.

The presented pilot teachers’ training has been delivered in the frame of the ELITe [3] Erasmus+, KA2, project, which underlying concern is to support STEM teachers develop knowledge, skills and attitudes for inquiry and reflective practice, so that they can effectively address their roles as lifelong learners, facilitators of students’ learning and members of educational communities. The project’s approach to STEM teachers' professional learning (Learning in Teaching via e-inquiries) foresees inquiry and reflective skills practiced through an inquiry-based learning (IBL)
methodology supported by digital means, as a way to facilitate teachers’ competence development. The approach is based on the principle that a teacher teaches in such a way that he/she was taught.

The teachers training aims to achieve two goals. At one hand, as a direct goal, the teachers to develop their skills for design, logistics and delivery of open air holistic lesson, applying different innovative methods and tools for assessment learners’ achievements and for evaluation of setting and process of this educational process. Special attention is paid to forming school teams of teachers in different STEM disciplines, able to design, implement and assess together and interdisciplinary STEM open lesson, having in mind the requirements of the national standards and curricula in involved STEM subjects, incorporating them into a holistic educational scenario, related to the real life application of the STEM disciplines learning material. At other hand, in parallel, the training is aimed at development of the teachers’ researchers’ competences, communication and problem solving skills, and their critical thinking.

The paper is structured as follows: Section II presents the background theory on which current approach is based, learning scenario aims, and methodology used. Section III presents the implementation of the scenario. Section IV discusses the results of the experiment, including observations and teachers’ reflections. Finally, lessons learnt are summarized in the conclusions.

2 METHODOLOGY

2.1 Inquiry and Reflective practice

According to Barnett & O’Mahony [4], the term ‘reflective practice’ can be considered synonymous with ‘reflection’: learning process examining current or past practices, behaviours, or thoughts in order to make conscious choices about future actions. This definition implies that reflection is the combination of hindsight, insight, and foresight.

Research or inquiry is a reflective practice of professional development. Its special feature is its publicity. An inquiry process, along with learning from this process, is intentionally designed to be shared [5]. It covers a variety of qualitative pedagogical research methods – self-study, auto-ethnography, action research, teaching as inquiry, and spiral of inquiry. The common feature of all these inquiry methods is the focus on understanding human beings in a social world where human beings are the educators/teachers and the social world is the school and/or classroom setting.

The inquiry and reflective practices go together as inquiry practice, is a form of reflective professional development in teachers’ practice. Their relationship is clearly described by David Kolb’s model [6] “What? So what? Now what?”. To facilitate educational practitioners – teachers and teacher educators, Barnett and O’Mahony. [4] (Barnett & O’Mahony, 2006) adapt the model, inserting the terms of ‘socialisers’, ‘reflectors’, ‘analysers’ and ‘doers’ (Figure 1).

Figure 1. Kolb’s adapted model
2.2 Learning scenario

When teaching science, there is a necessity of building a common picture of the nature. It is natural that this picture to be created in the nature. Interdisciplinary learning is integrated in most science subject curricula, but there is a lack of rich experiences in working in teams of teachers and design such education. In addition, applying the IBL model requires more specific teacher competences. It is still difficult to organize outdoor lessons in Bulgaria – there is quite a hard procedure and new set of normative documents, which need to be prepared. To implement outdoor learning processes, STEM teachers need to develop competences to prepare such documents in accurate and efficient way. Open-air lessons by themselves are challenging for students and for teachers. The scenario is designed to support teachers to face these challenges.

The teachers’ training scenario aims at:

- Becoming familiar with normative documents related to organizing and delivery of open-air lessons.
- Building skills to prepare documentation related to outdoor education.
- Motivating STEM teachers to organize and deliver outdoor lessons.
- Improving teachers’ skills to plan, organise and assess students’ activities during open-air IBL education.
- Developing competences to design non-traditional lessons.
- Forming and developing key teachers’ competences for open-air (in natural environment) lessons delivery.
- Development of team working competences.

After the training, the participating teachers would be able to:

- Prepare all documents necessary to be authorised for open-air learning;
- Design open-air IBL interdisciplinary lessons on given topic;
- Work in a team with other STEM teachers in the school;

and will experience what their students would like to reach.

The training scenario follows the weSPOT [7] six-phase model: Problem/Topic, Operationalisation, Data collection, Data Analysis (processing), Interpretation, and Communication.

2.3 Methodology scenario

The study applies inquiry and reflective practice as a qualitative research method. Following the maxim teach as you preach, the Problem/Topic phase was designed as a meta-training, where the teachers are in the role of students. They had a task to observe and reflect on their own behavior, challenges faced, solutions found, and team work issues. The aim of this phase was to support development of their professional competences related to their role of researchers in the classroom. During other phases, the participants should explore the regulatory documents and rules for organization of open air lessons, to collect the necessary documents, to choose a right time and topic for holistic open air lessons for their students. IBL scenario, tasks and learning resources should be developed in teams of STEM teachers.

Each phase contains a sub-phase for reflection, following the inquiry and reflective practice model. The teachers’ trainers act as partners, supporting the inquiry process and the moderating by relevant questions the reflection process.

The results of the teachers’ training model, and particularly – of the given scenario implementation, are extracted trough analysis of the trainees reflections on each phase. In addition, assessment of the training process is performed on the base of the products – IBL scenarios, learning resources and assessment methods and tools, developed by the participants during and after the training.

3 SCENARIO IMPLEMENTATION

The training was organized in two sessions:
- Face-to-face: meta-training, applying IBL approach in open air lessons, and reflection
- Distance-learning session for self-inquiry-based learning and preparation of final product.

The face-to-face session took place in a holiday camp called ‘Cedar’ (the name was integrated in the next tasks). The teachers were grouped in three competitive teams, assigned to the following tasks:

- To find hidden parts of a crossword puzzle in the camp garden, to assemble and solve the crossword puzzle. A common map was provided (Figure 2).

![Figure 2. Map exploration](image)

- To calculate the area of the garden.
- To research bio-diversity in the garden, calculating different kinds of flowers, shrubs and trees per square meter. The teams should be ready to provide artefacts proving their results (Figure 3).

![Figure 3. Field research](image)

- To contribute to the promotion and/or saving the holiday village, creating advertisement, tables, etc. from natural material found in the garden (Figure 4).

![Figure 4. Joint team efforts on the tasks](image)
To present the results and to provide reasoning (Figure 5).

**Figure 5. Reporting results and providing reasoning**

**Settings:**
- The teams were allowed to use mobile phones, sheets of paper, pens and natural materials found in the garden but not harming nature
- In this case, it was lightly raining during the training.

The teams had one hour for completing their tasks and an hour for a group reflection on it. The results showed different approaches to the tasks (measurement by feeds, using mobile apps – maps, calculators, internet, etc.) and creativity – not only in art tasks, but also in reaching results in other tasks. At the end of the session the trainees shared in the DojoIBL system [8] their reflections – feelings, thoughts, troubles, insights, etc., they faced during the pilot. During the reflection they were directed through questions:

- How did we act as a team? Was there a leader? How did we distribute the tasks among the members? How did we verify and validate the results?
- In which tasks we performed better than other teams? Which features / conditions / characteristics of the team members helped us?
- Where we failed? Why the other teams performed better? What was wrong in our work? How could we approach the task in a correct way?
- What we have learnt? Did the activity reflect on our relationships? Did everyone participate equally? Were all of the members able to present the best of themselves? How each of us assess the contribution of other team members?
- How the gathered experience could be transferred in my classroom? What practices I would use (even adapted)? What practices I would avoid?

As the system provides a shared space, the most of the participants were inspired by others’ trainees’ reflections, to find out a new aspects of a problem met, to evaluate lessons learnt, and to generate new ideas.

The face-to-face session finished with a summary on what is necessary to be learnt before organising open-air lessons, what normative documents shall be prepared, what potential constrains shall be considered and how to include all student even if some of them have some kind of disability or cannot participate in person (Figure 6).
During the distance session teachers continued working in teams, studying good practices provided through the DojoIBL platform, preparing documents required by Regional Management Centres of Education, sharing resources, developing lesson plans, looking for appropriate places for one-day or longer educational activities. At the end, each team published their own design, resources and related documents for open-air learning. The training finished with reflection, feedback and evaluation.

4 RESULTS

4.1 Observation

During the face-to-face session, the teams approached the task in different ways.

Solving the puzzle task, all the teams have worked together. We observed that in one of the teams there was a strong leader, guiding other members. The other team’s members discussed each idea before taking an action, while the third one worked at a whole, approaching spontaneously different subtasks. It is interesting that the task was accomplished correctly in a similar timeslot.

Solving the task about the area of the campus, one of the teams compared the object with known area (cottages) to the whole campus and calculated an approximate value. The second one firstly approached the task, assuming that the shape of the campus is rectangular and by measuring the sides by foots. Noticing that it is not a rectangle, even more – not a quadrilateral, it changed the strategy. Members used mobiles to map the campus and to measure the sides of the polygon, next divide the surface to known figures – rectangles and triangles, and calculated the area. The third team started with searching reliable information on the internet via mobiles, but, failing in this, they have been re-oriented to ask for such information on the reception. At the end of the competition, the third team shows the most correct answer, saving time for other tasks. The second team was very near to the right answer but loose lot of time, while the first team was far away from the correct area.

The bio-diversity task was approached in a common style by all of the teams – all of the participants has collected pictures of the found flora representatives as reasoning of the solution. One of the teams has divided the work in subtasks (flowers, shrubs and trees), distributed among the members. Here the correct accomplishment depended not only on the counting task, but also on the correctness of the calculated area.

The creative task engaged participant in different activities. One of the teams started directly with an idea for advertisement, collecting material and design of a poster. Another team started with internet research on legends about cedar tree and hidden symbolic that it presents. After that they have designed their metaphor of the campus – a model of the Noah’s ark. The third team prepared gifts for customers, putting their messages about the garden and its safety.

Continuing with reflection, at the beginning the participants were very short in the DojoIBL system, trying to find out the right answer. After some ice-breaking and mediation by the educators, they started share orally some feelings and thoughts. A little bit later the first one crossed the border of writing reflection, and all of the others, inspired by him, stated commenting and adding input. Actually, the process looked like avalanche – every reflection led to many comments, new ideas, remembering something, and adding new input (Figure 7).
At the end of the distance session, all of the participants, someone in teams, presented ready for use open air learning scenarios. Something more – two teachers from different schools developed a common scenario for shared ‘green school’! The greatest result was shown by the teachers from the First Private Mathematical Gymnasium, who implemented the open air lessons six months later. There were two teachers participating in the teachers training – chemistry and ICT teacher, but in the implementation there were involved also biology, math and sport teacher. They, all together, were developed scenario, tasks and resources for three-day open-air learning for 5 and 6-grade students during the winter holidays.

4.2 Teachers’ reflections / inspiration

At the beginning, some of the teachers were frustrated by the bad weather (cold wind and light rain). Regardless the fact, they completed the tasks and they shared afterwards that then they realised how important fun is during the learning process. Running in the garden, having fun, and competing with other teams, were evaluated as a real motivation-providing environment for invisible learning processes.

The reflection also reveals a deeper understanding of teachers that people learn in different ways, and open-air learning in a combination of inquiry and creative tasks provides the necessary conditions for people with different learning styles to perform well. Some of their reflections:

- **I realise my need to learn more and more. We may be afraid of open-air lessons because they are complex and we are not sure we are competent enough (or even as competent as students in some aspects – for example using mobile devices)** (Vyara)

- **Actually, a classroom cannot provide such atmosphere and environment that enables students not only to learn, but to feel the deepness of relationship across different STEM disciplines. But you need a very strong team of other STEM teachers to be able to design such learning process.** (Ivo)

- **We are used to being ‘right’. But this funny competition showed us that even we, teachers, shall be more critical of our knowledge and skills. Applying the same approach with students, we can manage it in order to developed students’ critical thinking** (Tanya)

The teachers realized that in the traditional classroom we usually expected individual performance of students and undervalue the teamwork, assuming that there is no way to assess each member contribution. After the face-to face session they aware that the team provide an atmosphere of safety for low confident member or those, who are not so competitive by themselves, and stimulate them to participate equally, to provide support or to present better. They shared also that the challenges provided by the unknown place, open air activities, the weather, etc., aimed at forming better relationships in the team and development of the supportive environment there.

Not at last place, all of the members value the holistic approach implemented. They shared that such a way of composition of small task, related to different STEM disciplines, really would provide students with a big picture of the nature, the relationships and dependencies there, and would increase the motivation of learning STEM.
5 CONCLUSIONS

Critical reflection allows us to learn from our mistakes, examine our actions, evaluate them against prescribed norms, alter them for success, repeat successes, revise and plan continually [9].

As the teaching context is changing permanently – in terms of wide and national policies, generational differences, new technologies development, etc., practicing teachers need to be given opportunities for professional development in and during their practice through critical inquiry reflection. By reflexivity, past and present events are reviewed in the light of possible futures.

Although the teachers are adult people, the fun during the training is a powerful tool for overcoming bad attitude to non-traditional learning methods, as well as to break the ice and to ensure the full engagements with the training activities.

In addition, critical reflection promotes developing networking opportunities, making friends, building confidence and self-esteem, enhancing team-working skills and developing leadership skills. These benefits form a basis for ensuring lifelong teacher support by the professional community, so that each teacher feels free to reveal their weaknesses and express their fears, taking support by their own experience as well as of community members’.

Experiencing the same style of teaching that is expected teachers to apply in their practice, is a challenge, but also has a very high added value. Being teachers’ trainers, we should have a very clear idea about the goals and to lead them in such a way that they understand not only of the teaching methods, but also different constrains related to the design and implementation.

The presented pilot shows that the inquiry & reflective practices help participants to demonstrate their willingness to share materials and resources they used, ways they might change them in different contexts – according to student specifics, ways of delivery, etc. Participating in a meta-course, accompanied by a reflective practice, supports teachers in development of professional competences as well as in transferring the experience to their classrooms.

Forming a strong professional community during the training is the responsibility of the teacher trainers. Succeeding in this leads to a long-lasting learning effect and continuous community support to the trainees.

Last but not least, by inquiry and reflective practice the teachers develop their competences for pedagogical research on the field.

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