# *In the Dinosaur' Steps* through IBL Scenario: A Way to Overcome Prejudice for Career in STEM

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Abstract: The Inquiry-based learning (IBL) is a powerful learning approach, especially in the field of science, technology, engineering and mathematics (STEM). This paper presents the implementation of an IBL scenario for teachers' competence development aiming to overcome students' and their parents prejudice for scientists and scientist's profession, and to encourage them to get interested in STEM career. *In the Dinosaurs' steps* experiment students have to *become* researchers in a Paleontological museum, taking part in different training activities and sharing impression about the scientists' profession. In parallel, observing actions of the students, teachers had to acquire professional competences for design of learning activities so to find a way to overcome the most popular bias and prejudices toward the career in STEM. How scenario succeed to convince future scientists to continue *in Dinosaurs' steps* is presented through participants' answers of the questions. The most valuable result of the experiment is the IBL scenario, developed by a teacher, who transferred her experience from the experiment into her own classroom. Finally, the paper summarizes some opportunities for applying IBL in STEM teaching – joining the efforts of educational, scientific and cultural institutions and bringing together teachers, parents, scientists and experts.

## 1 INTRODUCTION

The recent debates about the jobs of the future raise the issue of the tremendous gender disproportion in STEM jobs, noticing that more girls have to be encouraged to join the science career. The recent in-depth studies of Microsoft in EU (Microsoft, 2017) and USA (Microsoft, 2018) reveal the key factors influencing the girls' interest in STEM – having practical, hands-on experiences, female role models and exposure to STEM jobs, encouragement and support from teachers and parents, possibility to explore creativity and real-world impact in STEM.

On the other hand, the jobs of the future will raise the demand for complex competences such as critical thinking, creativity, complex problem solving, teamwork and mastering innovative technologies (Caena, 2011). In this context, students have to be stimulated to be pro-active, building knowledge from first-hand. Therefore, teachers should be able to take a new role of mentors, supporting students' learning via more innovative active learning methods.

Inquiry-based learning (IBL) is an active learning methodology, empowering students to take the role of researchers and scientists (Nikolova, et al., 2018), driven by their curiosity. In IBL, teachers organise the learning process in a meaningful context scenarios, where students can build new knowledge and skills from their own personal experiences, reflections and insights.

It is important to highlight that successful implementation of active learning methods depends on the teachers' attitudes, professional and social competences, and experience (Nikolova and Stefanova, 2014). Therefore, the application of IBL approaches requires new teaching skills and competences. Teachers should develop competences to adapt and apply new technologies in the teaching process, to assess critically new learning resources and to be able to evaluate creative and non-standard ideas of the learners, to conduct pedagogical research in their classrooms, to organise / participate in professional discussions and analysis of their work. Another important issue is the ability of the teachers to interpret the complex competences and to teach learners how to acquire these key competences (Nikolova, et al., 2018).

This paper aims to present and discuss an IBL scenario as an effective teachers' meta-training - involving them in an IBL experiment, encouraging



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students orientation to research career in STEM. The IBL scenario *In the Dinosaurs' Steps* has two goals addressing teachers’ competences and students’ attitudes. By observing and reflecting on their own experience, students had to investigate what are the key aspects of the researchers’ career. On their turn, teacher’ inquiry focuses on approaches and activities, promoting gender equality and fostering girls’ interest to science. The experiment is organised in the framework of the event "European Researchers’ Night 2018”. It took place in the Museum of Palaeontology and Historical Geology at Sofia University "St. Kliment Ohridski", Bulgaria. The name of the scenario *In the Dinosaurs’ Steps* aims to provoke both students and teachers, making a parallel between the objects in the Palaeontology museum – fossils, footprints, and skeletons from the past and the *dinosaurs* – the scholars whom children often portray as elderly people from nineteen century with obsolete concepts and methods.

# 2 METHODOLOGY

Inquiry-based learning has been identified as one of the most powerful innovative teaching approaches for raising scientific literacy of the learners, as well as for teachers’ competence development, stepping on ***inquiry and reflective practice*** (Earl and Ussher, 2016). The *reflective practice* in education is usually characterized by 1) looking back to own practice and thinking about the experience and possibilities for improvement or going closer to the desired state; 2) exploring possible solutions and alternatives; 3) taking evidence-based decision and 4) evaluating results of its implementation which is actually the first stage of the new reflective cycle. The term ‘reflective practice’ can be used as a synonym of ‘reflection’, defied by Barnett and O’Mahony (2006) as a 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* (Barnett and O’Mahony, 2006).

The critical reflection allows learners to learn from their own mistakes, examining actions, evaluating them against prescribed norms, alter them for success, repeat successes, revise and plan continually (Krishnamurthy, 2007). In addition, critical reflection promotes developing networking opportunities, making friends, building confidences and self-esteem, enhancing team working skills and developing leadership skills.

According Earl and Ussher the IBL approach, enhanced by a group reflective practice, is much more powerful, because the inquiry covers variety of qualitative pedagogical research methods such as self-study, auto ethnography, action research, teaching as inquiry, and spiral of inquiry. *An inquiry process, along with learning from this process, is intentionally designed to be shared* (Earl and Ussher, 2016).

Among the main difficulties for teachers to implement IBL in the classroom, is the lack of own experience in it. Usually, the teachers’ training courses are conducted in a traditional way via lectures. Therefore further attention should be paid on using inquiry and reflective learning model for teacher’ training as *the teacher teaches in such a way in which he/she was taught.*

The presented IBL approach consist of design and implementation of specific learning scenario, following the weSPOT IBL six-phase model: Problem/Topic, Operationalisation (realisation of the idea with the aim to measure), Data collection, Data Analysis (processing), Interpretation, and Communication (Mikroyannidis at al., 2013).

The described IBL scenario interweaves formal and informal learning, involves different stakeholders - parents, scientists, experts, museum workers, etc. It provides opportunities for learners to meet scientists and STEM experts, to find role models among them and to get better understanding of the impact of the scientific work.

An important part of implementation this approach is the reflection, the self-observation, the group sharing and reasoning the new knowledge and skills acquired on each stage. For presented experiment it is chosen the DojoIBL (https://dojo-ibl.appspot.com) platform, which supports IBL in general and particularly feedback sharing, group reflections, surveys and queries, allowing scenarios’ further analysis and replication.

For teachers, training on how to design and conduct STEM IBL scenario through IBL pedagogical scenario cares significant added value – real, experienced by themselves, model; possibility to extract good practices for their own audience, raising attitude and awareness to own professional development by self and group reflection.

# 3 EXPERIMENT AND CONTEXT

The experiment was designed and organised as an IBL scenario *In the Dinosaurs' Steps*. Its objectives were to explore how an IBL scenario can put students and teachers in the role of researchers during the visit of Palaeontology museum and a *science fair*-type of event. Therefore, both teachers and students had to observe and investigate different elements while taking part in the tasks and activities organized during the event "European Researchers' Night – 2018". The experiment covered part of the IBL scenario phases: data collection, data analysis, interpretation of the results, and the communication phase, which was partly addressed – mainly through questionnaire which results are presented later. Due to time limitations and organisational setting, the phase of problem/topic definition and operationalisation were pre-defined by teachers' educators (the activities, stands, games, surveys, data collection models and techniques were designed beforehand). Teachers also took the position of learners, who together with their students received their tasks on place.

More than 130 children took part in the completion of the *In the Dinosaurs' Steps* IBL scenario. The majority of the pupils were approximately 10 years old. There were organised in groups, accompanied by 7 teachers in total. In addition, children who came accompanied by their parents also took part in the scenario.

## 3.1 Students' Activities

The scenario for students aimed to improve the pupils' perceptions and attitudes for the profession of the scientists. The students had the task to reflect on the researchers' career and the opportunities that the scientific path give to acquire valuable knowledge and skills for the future.

Before entering in the museum, the children had the opportunity to take part in biology experiments measuring bones, putting down their own fingerprints and observing them through the microscope. Before the museum visit, they received also additional material (Fig. 1, 2, 3). The educational activities in the museum were organised based on the children's age. The primary school pupils had to find out more information about the Deinotherium, and to discover the specifics of its diet and its natural environment. They had to choose the relevant pictures and to write down the scientific name of the Deinotherium in the provided to them worksheet (Fig. 1). The fossils of the Deinotherium were discovered in Bulgaria and it represents the biggest skeleton in the University Palaeontology museum.


Figure 1: Worksheet for the task about the Deinotherium diet and living conditions.

Another task (and relative worksheet) for students (Fig. 2) was to walk around the museum and to choose an object or artefact (bone, skeleton). Then, they have to sketch the artefact, and to investigate more information about its story, as for example the fossil name, its diet, its way of movement, natural environment, ecosystem and threats.

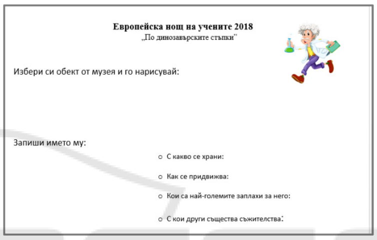


Figure 2: Worksheet for a task for making a sketch and investigating fossils' living conditions.

The students had the task as well to imagine and design an artificial creature based on the real fossils. On the worksheet (Fig. 3) they had an example illustrating how palaeontology fossils inspired people to figure out ancient mythology creatures like dragons. Students can draw their own magical creature and decide how to transform its real features into magical ones.

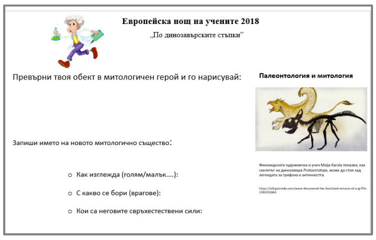


Figure 3: The worksheet for making a sketch and inventing a new mythology creature.

Finally, students could figure out a story about this creature composing a short storyboard, a comics or computer game. All students had the possibility to consult researchers and scientists in the museum, to work together and share experience, to ask questions and investigate information in Internet. All of them, who succeeded to fill their worksheets, received small gift. It has to be stated that all these activities and the tasks before and during the visit of the museum influenced to a large scale of questions and answers of the researchers' career.

After taking part in the Researchers' night event, including numerous games, experimentation stands in the museum and university, meetings with scientists, lecturers and demonstrators, pupils had to write down their observations and impressions in a prepared in advance picture questionnaire. In this perspective, the students' scenario did not addressed building specific STEM knowledge, but mostly – building inquiry skills and attitude to the science and scientific career. However, in correspondence to teachers' training scenario, it draw their attention on *what is to be a researcher;* what are students' associations, relate to the scientists' characteristics; are there some patterns; is there a significant difference in the boys' and girls' views; are there obvious prejudice, still prevailing after the event, challenging teachers future work.

### 3.2 Teachers' Activities

The focus of the teacher's scenario is on pedagogical research on design, delivery and evaluation of IBL STEM out of the classroom, so to overcome some of the popular biases and misconceptions about the career perspectives in STEM sciences. Teachers had to observe and investigate if their students find *the STEM sciences boring* or not and what activities provoke their conclusions, did the students share the gender prejudices that S*TEM are only for boys* or not and what they did or see to take such decision. Teachers' activities included also hands-on practice on students reflections and discussions management – they had guides on how to develop questions for discussion and reflection, and how to manage it such a way, that lead students to awareness and evaluation of the experience and the lessons learned during the event. At the end, the teachers had to reflect on which of the activities and games in the museum help to overcome these most popular stereotypes. They should also reflect on the way of their own professional development through *live* participation in an IBL process.

In order to complete their mission, in the beginning of their visit to the "Researchers' night" event, teachers received instructions about the IBL scenario (preliminary designed by authors as teachers' educators), supplemented with materials about different aspects of the competences of the future, the role of critical thinking and creativity for the professions of the future, as well as resources about the impact of the IBL for acquiring new knowledge and skills. Before starting the training, the teachers had present informal pre-survey, as a experience and opinion sharing, about their understanding and knowledge on the main prejudices and misconceptions about STEM, both for students and parents. Then, during the conduction of the IBL scenario, the teachers had to observe the attitude, the interest and the behaviour of the students and what activities provoke them so to form positive attitude to science.

After completing all the activities by students, teachers had to share, using DojoIBL system, reflections and feedback about this experience. This time, they had to reflect on their understanding of the origins of the biases and the main methods and approaches for overcoming students and parents' misconceptions and prejudices for STEM sciences. Teachers had to evaluate their competences to use interactive teaching approaches, including IBL approach, assessment models of the students' learning achievements during the application of IBL approach and effective methods to overcome gender prejudices and misconceptions about the career in STEM. At the end, the teachers had to evaluate their attitude on collaborating more intensively in the teacher-student-parent triangle, working in teams and involving more stakeholders in these interactions such as scientists, other teachers, or parents' communities.



## 4 ANALYSIS OF THE RESULTS

The analysis of the experiment's results is based mainly on participant's feedback. It reveals the effect of joining the *In Dinosaurs Steps* IBL scenario.

### 4.1 Students' Results

The questionnaire for collecting the students' observations (Fig. 4) consists of ten open picture-questions, where students have to answer with their own words.

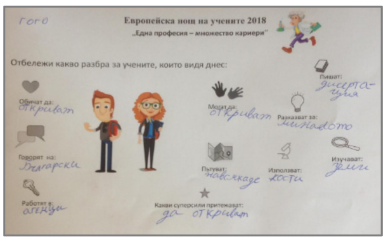


Figure 4: A questionnaire filled-in by student.

Data is presented below. The blue (left) wordless reflect the boys' perceptions, and the red (right) – the girls' ones.

The data analysis shows that on the question *What do scientists love*, most of the children answered that scientists primarily love to **learn**, to **study**, to **explore** and to **discover** new things. ***Boys*** are impressed mostly by the ability of the scientists to *make inventions* and to *experiment*. ***Girls*** want 'like them' *to travel around the world* and to make *archaeological discoveries* (Fig. 5).


Figure 5: What do scientists like to do?

After the talk with scientists in the museum, it is not surprisingly that the question *Scientists speak on/talk on ...* received the most responses 'Bulgarian language', but there are also answers like 'Scientists know English, Latin and German'. In rare cases, *boys* find scientific language *difficult*, *secret* and *incomprehensible*, while for *girls* it remains *understandable*. Boys describe the scientists' audience divided on interested, colleagues and ignorant. For girls, the audience includes curious children and visitors, friends and tourists. Girls are impressed by the low and calm voice of the scientists. All students are confident that the scientists speak on phone and write short messages (Fig. 6).

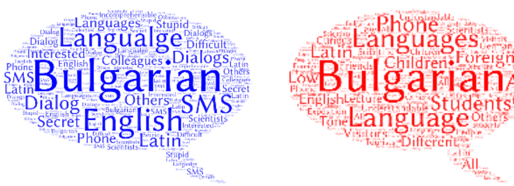


Figure 6: The scientists speak/talk on...

Students' answers on question "*What tools do scientists use in their work?*" are linked, in most of the cases, to the tools used by themselves during the activities in the IBL scenario. According to participants, the scientists use in their work various equipment. Most of the students find that the *microscope* is the main research instrument, but there are other tools like *modern technologies*, *telescopes*, *appliances* and *magnifiers*. There are *bones*, *imprints* and *periscopes* among ***boys'*** answers and among the ***girls'*** ones there are *telescopes*, *books* and *apparatus*. According to the *boys*, the *scientists* use their *mind*, and according to the *girls*: *many words* (Fig. 7)

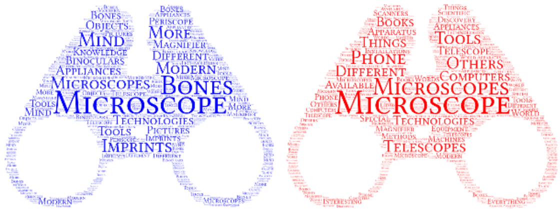


Figure 7: What tools do scientists use in their work?

According to the students understanding after finishing IBL scenario activities, scientists study dinosaurs, bones of extinct animals, natural phenomena, history and biology, the world around them. Among the **boys'** responses are *science*, *phenomena*, *artefacts*, *Universe*, and among the **girls'** answers, more interesting are *students*, *lost creatures*, *ruins* (Fig. 8).


Figure 8: What do scientists study?

Based on the observation and work done by students in activities of IBL scenario, *scientists can primarily write and read*, *discover interesting things* and *make experiments*. They can observe, study, think and take important decisions. **Boys** think that researchers can *observe everything* and *gather knowledge* while girls are impressed that scientists can *take fingerprints*, can *solve problems alone* and can *educate children* (Fig. 9).


Figure 9: What scientists can do?

A part of the activities in the scenario leads also to the answer of the question *What do scientists write about?* According to students, scientists write *papers* and *books*, *scientific articles* and *reports*, *essays*, and *homework*. According to **boys**, scientists describe their *scientific theses*, *ideas*, *topics* and *secrets*, and according to **girls**, they write about *mathematical problems*, *discoveries* and *scientific theories.*

The presentation of scientists in the museum, lead the students to answer as follow on the question *Where do scientists travel?* – scientists can travel everywhere around the world, in Europe, in the jungle, on the pole, in the space, even in the past. They can choose an *interesting point on the map and organize an expedition to it*, to *explore nature* and *distant lands* (Fig. 10).


Figure 10: Where do scientists travel?

As the IBL scenario took part in university and its museum and laboratories, naturally students answered that the scientists work *mostly in a laboratory*, *university* or *museum*. It is interesting to observe that the pupils find that teachers in schools and colleges are also scientists. Scientists can work everywhere; according to the **boys** – at the *Bulgarian Academy of Sciences*, in an *agency*, in an *office* or even in a *garage*, and the **girls'** focus on *teamwork* in scientific group, in the *classrooms*, or even on the *field.* After completing activities in IBL scenario, students thinks that scientists talk about dinosaurs and mammoths, animal bones, about science and interesting discoveries they have made, about history and the past. These students understanding is naturally formed because a large part of the activities took part in the Palaeontology museum and they link it to the question. According to the **boys**, the most attractive topics cover *archaeology* and *future*, *space* and *Universe*. For the **girls**, the main topics of interest are the *curious facts*, the *electricity* and the experiences with *life sciences* and *new objects* (Fig. 11).

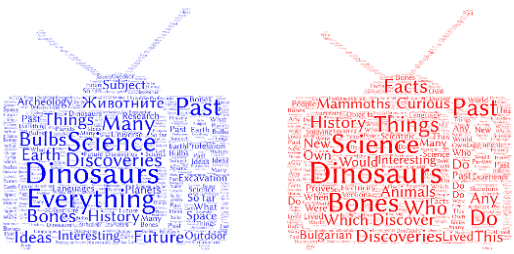


Figure 11: What do scientists talk about?

It is very interesting to see that according students observations, the main ***super power*** of ***the scientists*** is the ***mathematics***. Other distinctive skills are the ability to discover new things, an extraordinary and sharp mind and a lot of knowledge. **Boys** mention the *creativity*, *technological progress* and *fame* while **girls** appreciate the curiosity, *memory*, *magic* and *fearlessness* of scientists (Figure 12).


Figure 12: What is the superpower of the scientists?

Overall impression of the answers of all the questions is that through them students clearly demonstrate the respect to the scholars, the positive attitude to scientist profession and even willingness to follow the steps on *Dinosaurs*. In most of the cases boys and girls used one of the same works or words with the same meaning, which shows that all of them have common look on career in science, which makes us, as authors of the IBL scenario, happy with its result – overcoming prejudice for scientists and career in science. Some slightly differences in answers of boys and girls only confirms that both genders could contributes in science with their point of views. For teachers differences in boys' and girls' answers provide a clear pictures which points of view and gender specific characteristics to explore in the STEM classroom to attract all of the students neutralizing the potential impact of parents or society prejudice.

## 4.2 Teachers' Results

Seven teachers took part in the IBL teachers' training scenario. They filled-in online questionnaires and provided feedback and reflections in the DojoIBL system.

Observing the students work on scenario, teachers should think about what type of activities need to be performed by them in order to design such a scenario as well as what competences needed to poses so to organize it. With this in mind, teachers did the competence self-assessment on a scale ranging from 1 (very weak) to 5 (very good), and every question required two answers – before and after the experiment. Teachers' results show significant increase of their professional competences in terms of knowledge, abilities and attitudes. (Figure 13).

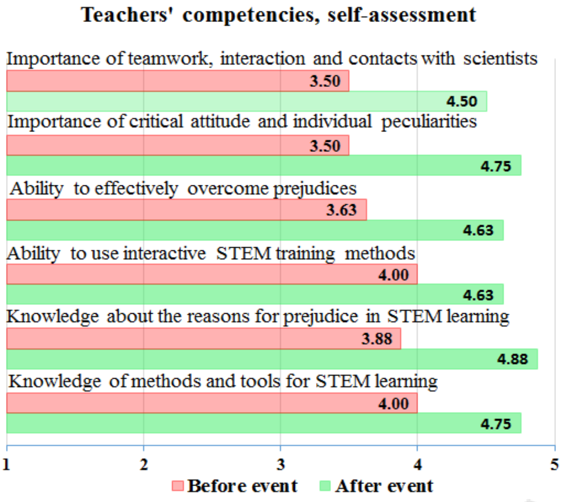


Figure 13: Self-assessment of teachers' competences.

During the delivery of the *In Dinosaurs Steps* IBL scenario, the teachers took part in different types of activities.

The other question asked teachers to evaluate how useful were different type of activities for them. In this category, the most appreciated were the practical and hands-on activities, followed by inquiry-based learning, reflection and metacognition, learning with peers and self-regulated learning (Fig. 14).

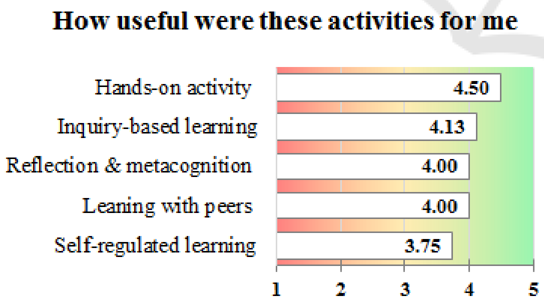


Figure 14: Activities evaluation. Usefulness.

The teachers evaluated the inquiry skills that they have developed in this scenario setting. The most experienced were communication skills, followed by analytical skills, metacognitive and reflection skills, information literacy, digital skills, critical thinking and other research skills.

All teachers manifested a strong interest to take part in further IBL trainings on similar topics.

The data, collected through the questionnaire does not provide enough information about the extent to which teachers are ready to design similar IBL scenario, promoting the science career for their students. But our team was happy to understand that two weeks later one of the teachers, participated in the activities, designed her own scenario during her classes at school. That was our most visible result and it is presented in the section below as the follow-up.

## 5 FOLLOWER OF DINOSOURS STEPS

The most valuable outcome of the IBL experiment *In the Dinosaurs' Steps* was designed and conducted by the STEM teacher Mrs. Tanya Dimitrova. She developed her own IBL scenario for presenting the researchers' career to her class of third grade students in the Primary School "Pythagoras". The first phase of the scenario aimed to provoke pupils by asking them to assume *what it is to be a scientist*. The pupils had to fill the same questionnaire, but without visiting the "Researchers night" event, museums or discuss beforehand.

Analysing the pupils' answers, the teacher discovered some interesting findings. For example, some of the children believed that scientists *love to do miracles*, *think logically*, *speak on their native language, but with many difficult and complex words*, *speak on many languages*, *work in special clinics for scientists*, and work in *houses full of inventions*. Some of the kids mentioned that scientists *experiment and do extraordinary things*, like *mixing DNA* or *mixing some potions*. Scientists talk *about the space* and about what *they learned from their discoveries*, use *chronoscopes* and other special tools. Scientist write a lot, about very complicated things in special *notebooks for failures and successes*, making *huge tables with different English numbers*. Scientists travel often around the world, use many *boxes for strange things* and many other.

The next phase of the IBL scenario consisted of invitation and class visit of scientists – prof. Ana Proykova and assoc. prof. Nikolina Nikolova from the Faculty of Mathematics and Informatics at Sofia University "St. Kliment Ohridski" (note that both of them are female, and this fact was not expected by some of the children). Prior to meeting the pupils, the scientists together with the teacher investigated the children's responses and attitudes and prepared suitable examples and experiments. During the meeting in class, the pupils had the opportunity to ask many questions like *how the telescope works*, is there a *chronoscope* device, *is there a common language* *reserved only for scientists*, *are there smaller particles than the nano-particles*, *is there a 'teleporting machine'* and others.

In result, after reflecting on their experience of knowing *real scientists*, most of the children have admitted that being a scientist is not scary but *fun, interesting and exciting*, and express a wish to become scientists when they grow up.

In its final phase, the typical IBL scenario includes communication and presentation of the results. In this case the teacher described and presented the children's experience on the official webpage of the school, which allowed other teachers and parents to learn about it. Furthermore, the story was published on social media, it was shared with other teachers from the IBL learning community, researchers and scientists at the university, and others.

The IBL scenario of Mrs. Tatyana Dimitrova invoked further interest and motivation of the children to take part in other scientific experiments and initiatives. They took part in a practical lesson of planting an acorn, getting excited about future active learning scenarios.

## 6 CONCLUSIONS

The implementation of the IBL scenario *In the Dinosaurs' Steps* opened many questions and showed new possibilities to encourage students for scientific career. Although the challenges and the efforts, needed to raise awareness and implement active learning approaches in class, IBL scenarios can be applied in both – formal and informal learning. This open the doors for active collaboration of teachers, scholars, scientists, curators, museum workers and gallerists in design of IBL activities and experiences for students. Furthermore, collecting and implementing different practical scenarios from a variety of application areas can increase the possibility of STEM teachers to design, plan and implement appropriate active learning scenarios in their own classes. In addition, the data, collected by students, reveals what kind of activities and / or perspectives are more engaging for boys and which ones – for girls.

The presented scenario can be easily adapted for students of different age groups and STEM subject areas. By allowing students to gain personal experience and reflecting on it, teachers can play a crucial role for motivating the new generation of professionals, both boys and girls, overcoming prejudice for career in science, with lasting interest toward STEM, following the *Dinosaurs' steps,* and ready for the professions of the future.

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