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STEM4you(th) project: The Astronomy course

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Abstract

This paper presents ten teaching scenarios based on Astronomy subjects, focusing on middle formal and informal education in the framework of European STEM4you(th) Project (Horizon 2020). Each scenario follows the STEM approach and has been formulated by combining the inquiry - based learning method with constructivism. The teaching material contains hands on activities, constructions, simulations, storytelling and creates a link between science and the labor market related to Astronomy and Space Science. Through these courses students learn astronomical subjects and through astronomy the processes of science. This course aims to motivate 14-16 year-old students to STEM disciplines, and enhance their scientific skills and their creativity. The final outcome of the project is an interactive platform where the produced educational material may be adopted by teachers throughout Europe.

Key words: STEM, astronomy, inquiry learning, constructivism.

Introduction

STEM is an instructive approach based on the idea of educating students in four specific disciplines (Science, Technology, Engineering and Mathematics) in an interdisciplinary and applied approach, by integrating them into a cohesive learning paradigm related to real-world applications. The goal is to promote science, technology, engineering and mathematics to all students in order to effectively engage themselves in public discussions, develop critical thinking, deal with every day related issues and information and, ultimately, choose careers in these disciplines (National Research Council of the National Academies, 2012). In 2014 a research agenda for determining the approaches and conditions most likely to lead to positive outcomes of integrated STEM education at the K–12 level in the United States of America was conducted (The National Academies of Sciences, Engineering Medicine, 2014). Students through STEM education develop high-level skills, work and learn together in an inquiry-based approach, familiarize themselves in finding interdisciplinary solutions to the problems posed and build and share knowledge. However, STEM education is not sufficiently introduced in the curriculums of European educational systems. This is the main reason why many European Projects about STEM are currently in progress (Brzozowy et al., 2017b).

STEM4you(th) is a European Project funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No. 710577. Its duration is 30 months starting from May 2016. Universities and Research Institutes from 6 European countries participate in the project: Politechnika Warsawska (Poland/Project Coordinator), Eugenides Foundation (Greece), Institut Jožef Stefan (Slovenia), Fondazione Umberto Veronesi (Italy), "Research Paths" (Greece), Technická Univerzita Ostrava (Czech Republic), Universitat De Barcelona (Spain), Universidad De Cantabria (Spain), Open Evidence (Spain), Institute for Strategic and Developmental Analysis (IRSA) (Slovenia). More about the Project are available on STEM4you(th) Project's WebPage (www.stem4youth.eu) and on Research Paths WebPage (www.researchpaths.gr) concerning the Greek contribution to the Project, news is posted on the facebook group @stemforyouth.

STEM4you(th) seeks to produce a comprehensive, multidisciplinary series of courses presenting key STEM discipline challenges to support young people, primarily junior high school students aged 14-18, in formal and informal education. The content is organized around 7 STEM disciplines: Mathematics, Physics, Astronomy, Chemistry, Engineering, Medicine and Citizen Science in schools. For each discipline 7-10 challenges are presented largely through their practical applications and their impact on our everyday life and work. One of the basic aims is to show which specific skills and competences are developed through STEM education and how these skills address the current and future European labor market needs.

In effect STEM4you(th) will provide a helicopter view of STEM disciplines and job characteristics associated with these disciplines, with the aim of helping young people take conscious decisions about their future (subject of, field of study and finally career path to pursue). The scope and tangible results of STEM4you(th) are: a) a multidisciplinary guide developed for different exploitation channels (concerning extra-curricular activities at school, science festivals, university organized lectures and open web-based self-study materials), b) formal and informal methodologies and tools tailored to present the scientific challenges in an attractive way (learning by experiment, gaming, citizen science at schools), c) recommendations on STEM learning best practices and formal school curricula (input to the EU education policy).

STEM disciplines apply to many sides of our life, including future jobs. The project involves teachers and students in learning STEM subjects in an innovative way inside and outside the school and encourages educational authorities to upgrade their activities across the school systems in Europe. To achieve this, courses are combined with interactive events in various venues (e.g. science festivals, pop up events etc.) at conferences involving local or national authorities, hoping that the innovative teaching of STEM becomes more and more part of education (Brzozowy et al., 2017b; Mantecón et al., 2017).

Astronomy Course

Astronomy and Space Science contribute significantly to other scientific fields. Their impact to everyday life includes calendars, industrial products, aerospace technology, medicine, satellite imaging, telecommunications, mapping and global navigation. Astronomy has strong connections with the STEM and human sciences' disciplines as well. This is reinforced by the Strategic Plan for Astronomy of International

Astronomical Union as science and space research are approached in an interdisciplinary way (IAU, 2009).

In the context of this project we have developed an astronomy course consisting of ten lessons with the following tittles: "Our Views about the Cosmos", "Our Solar system", "Travel in space", "The Sun", " Climate change and the Greenhouse effect ", "The use of satellites by humans and modern space related professions", "The contribution of Astronomy in the development of the scienes", "The Cosmos is comprehensible through Science" Cosmos" and "Modeling of the phenomena of the Cosmos".

The instructional objectives of each lesson were determined after taking into consideration the astronomical content of the lesson, the scientific processes involved, the students' misconceptions on each subject and the Nature of Science (NoS). Teaching means and materials used in the course are: storytelling videos, digital simulations (e.g. java simulations, PhET Colorado) (Esquembre, 2004), videos, images, hands on activities based on constructions with simple materials (e.g. Telescope, a greenhouse-like construction, Robotic hand) (Fig. 1), drone (with arduino based sensors onboard), worksheets, scenarios, presentations and evaluation sheets for the students. The use of storytelling videos in the lessons is of highly importance since it serves as a motivator for each lesson. Through stories students contextualize science in a manner that enables them to develop a better understanding of the nature of science. By being able to imagine situations and events in our mind, we may be able to develop a broader understanding of science. Moreover, we develop emotions and, thus, a relation to the personae in the narration. As a result, interest can be raised that may go beyond the story (Ellrod & Heering, 2014).

Hands-on activities and constructions bring students closer to engineering and technology. Students develop new skills and deal with problems that are solved with a critical and interdisciplinary approach (e.g. Sanders, 2009; Bybee, 2010a; 2010b).

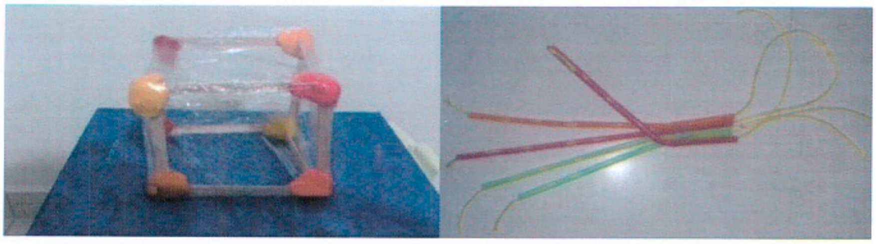

Fig. 1: Hands on activities – Constructions with simple materials (left: a greenhouse-like construction, right: Robotic hand)

Each lesson scenario is accessible through a specifically designed web platform, the Open Learning Content Management System (OLCMS). This platform has been developed in the framework of the Project (Brzozowy et al., 2017a) where all partners of the Project upload the content of their course (https://olcms.stem4youth.pl/discipline). The platform serves both as a repository of educational material and as educational resource supporting students and teachers. Lesson content and all materials (video, multimedia, instructions, software etc.) designed for the project are freely accessible at the Platform.

The aim of the project is to develop skills and aptitudes on many levels (cognitive, technical, collaborative, social etc.) and enhance positive attitudes towards Science, Technology and STEM related professions.

Teaching Methodology

The inquiry based learning method (e.g. Larmer et al., 2015) is used as methodology for each lesson combined with the constructivist approach.

The suggested teaching approach is based on the following theoretical assumptions:

- Student development is socially situated and knowledge is constructed through interaction with other students and it cannot be transmitted by the teacher. Thus, learning is developed through social interaction.
- Teaching is constructed from specific to abstract or from partial to general.
- The use of analogies in the teaching process connects the already existing knowledge of the student with the new knowledge.
- The cooperation of the students in small groups facilitates the social interaction and the learning process, especially in relation to difficult cognitive aims.
- Activities based on constructivist teaching, such as the promotion of the students' ideas by making their own hypotheses, and the meta-cognitive activity of comparing the initial hypotheses and the final conclusions, are also included.

The instructional procedure followed is in accordance to an inquiry-based learning method that includes the following steps:

- The phenomena
- Questions by the students
- Questions of the lesson
- Answers/Hypotheses
- Experimentation (data from simulations and images)
- Conclusion
- Comparison between the initial hypotheses and the final conclusions of the students.

- Generalization
- Extension/Application.

In the beginning of each lesson the teacher introduces the students to the subject that will be presented, using storytelling videos and images or videos. Students write down on the worksheet their questions in order to formulate the questions of the lesson. The Answers/Hypotheses are put forward and the experimentation activities (data from simulations, video, images, hands-on activities) begin. Students draw conclusions and compare them to their initial assumptions. Finally, the students may make generalizations or/and extensions/applications. At the end of each lesson there is an activity that links the content of the lesson to the STEM related labour market.

Evaluation of the course

The evaluation of the course is twofold: On the one hand, the evaluation of the attitudes is based on a pre- post research design and a number of semi structured interviews. Since aim of the project is to examine students' motivation to STEM, a questionnaire about their beliefs and attitudes has been unitlised that comprises a number dichotomous items, i.e. statements that students either accept or not. Students' answers will later be analysed according to the Rasch model (Bord & Fox, 2015).

On the other hand, the quantitative phase of our evaluation is based on written tasks assigned to students at the end of each lesson. The questions have been designed in a way that corresponds to the learning objectives (multiple choice and short answer questions).

The evaluation tasks have been designed on the basis of the following principles:

- The items correspond to the instructional objectives.
- The items are of various types in relation to their scaling (Likert like and dichotomous), as Kassotakis (2010) suggests.
- The attitude items are dichotomous, to allow for possible factor and Rasch analysis.

Astronomy course in secondary education (junior high school): Pilot Phase

According to the project the astronomy course is designed so as to be implements and assessed in Greek schools in two stages (Stage I & Stage II). The selection of schools and the recruitment of teachers has already finished since September 2017; the teachers involved have received the necessary training in order to implement the course. Stage I of the Pilot Phase in which 70% of the lessons were to be implemented, has already been completed in public schools of Chios Island, Piraeus and Athens. After the necessary feedback and the relevant corrections, the course is currently being assessed in its entirety for a second time. After the data processing from the second implementation the course will receive its final form.

Number of School	Age of Students	Number of Students	Number of Teachers
1	14	25	2
2	14	22	1
3	15	17	2
4	15	20	5
5	15	20	2
6	14	15	1
7	14	24	1

Table 1: Number of students and teachers involved during the Pilot Phase

Pilot Phase (Stage I) Results-Discussion

The feedback from the first stage (Stage I) of the Pilot Phase of the Astronomy course is encouraging. The majority of the students were very keen in involving themselves in hands-on activities. They were also enthusiastic about storytelling videos, other scientific audiovisual material and simulation videos as well. The results show that the duration of each lesson depends on the number of the students involved. The duration of the hands-on activities should be determined with greater precision so as all lessons may have a maximum duration no longer than 90 minutes. The evaluation has so far indicated that after the intervention students have more positive attitudes towards STEM and a much better understanding of Astronomy. The drawbacks mentioned in the Stage I of the Pilot Phase have been taken into account for Stage II. The majority of the students (according to the questionnaires) stated that they wish to be involved in STEM related activities again. The results so far indicate that students are especially keen on participatory, group activities (constructions and experiments), that give them the initiative to deploy their creative skills.

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