«Odyssey» Scientific Debate: Rhetoric and STEM education

Foteini Egglezou

1. Introduction

Odyssey: Oxford Debates for Youths in Science Education is a European research Erasmus+ KA2 project between institutions of four European countries: a) Poland, b) Serbia, c) Esthonia and d) Greece. The project is addressed to students of secondary school (13-19 years old) aiming at improving their: a) reasoning, b) communication, c) argumentative, d) critical, e) linguistic and f) cognitive skills within the context of STEM education through the introduction of debating. In Greece, the testing stage of *Odyssey* started on October 2019 and ended on June 2020 with the participation of 11 Greek schools (9 Lyceums / Upper Secondary Schools and 2 Gymnasiums / Junior High Schools), while, the involvement of at least, 32 schools from the four participant countries (8-16 schools per country) is intended. The project *Odyssey* emphasizes the importance of teaching Science to all students, independently of their professional orientation, and not only to those that will find their vocation as scientists (Weber 1958). Modern societies need democratic citizens, acquainted with scientific experiences (Sengul 2019) such as the problem-solving through the use of logic and language, in order to make reasonable choices not only as scientists, but, also, as voters, consumers, professionals in everyday life. In other words, the project *Odyssey* intends to cultivate independently thinking students that can comprehend and

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evaluate the received information using it in an appropriate way and contributing to the general welfare.

For achieving this goal, *Odyssey* introduces debates as an appropriate didactic strategy for the examination of controversial scientific issues in classroom, since opposite scientific views are not "contrary to reason" (Dearden 1981, 38) and merit an accurate search about their correctness "even if we do not attain" it (Dearden 1981, 40). Within this context, the scientific knowledge is not considered certain and objective (Dewey 1910; Hadzigeorgiou 2015). On the contrary, it seems to be also interwoven with socio-political, ethical and economic dimensions of real life problems (e.g. militarization of space) as well as with provided data which are complex or 'uncertain', since their interpretation 'differs' (Levinson 2011, 60). Undoubtedly, the realization of debates as didactic strategy in STEM education presupposes the acceptance of science as argument (Erduran and Jimenez-Aleixander 2008; Sampson and Clark 2008; Cavagnetto 2010; Kuhn 2010) and the critical dialogue between claims of knowledge (Ford 2008a; 2008b).

2. The intellectual materials of Odyssey: Science as body of knowledge and as process

> "Science is built up of facts as a house
> is of stones, but a collection of facts is no more
> a science than a pile of stones is a house".
> Henri Poincaré (1917), *La Science et l' Hypothèse*

The educational project *Odyssey* is innovative, since it brings out the dual nature of Science, as both: i) a body of knowledge and ii) as a process (Millar 2004, 1). On the one hand, science, as body of knowledge, became accessible to the participant students and teachers of *Odyssey* due to the use of prepared educational material (Intellectual Output O8) concerning five controversial scientific issues. The five scientific educational packages (O8) provided the necessary scientific information on each examined topic. In more, the authors of the packages conducted a webinar for each issue in which they presented the main theoretical notions of it and set the scientific framework for the further research for both educators and students.

On the other hand, the comprehension of science as process was achieved through the introduction of argumentation and debates as an organic didactic strategy in teaching and learning STEM. Two methodological guides intended to facilitate students' and teachers' access to the teaching of argumentation and debates:

a. the intellectual output O3: «National Frameworks for Implementation of Oxford Debates in STEM in School Practice» (2019). The prementioned guide sets the framework for the implementation of the project while it includes seven lesson plans which intend to facilitate students develop the required skills for successful debating such as communication, argumentation, searching for evidence, linguistic skills as well as knowledge about debating rules, rebuttals, refutations and fallacies.

b. The intellectual output O4: «Methodological Guide Odyssey: Oxford Debates for Youths in Science Education» (Egglezou, 2019) which fully describes the debating process and its rules.

More precisely, during the school year 2019-2020, the Greek students had to study the provided educational material of the intellectual output O8. After the examination of each topic, students participated to a correspondent debate contest in classroom. In Greece, the five educational packages, written into the national language as well as translated in English, stemmed from inquiry based upon reliable scientific sources and they were dedicated to the study of: i) *Nuclear Energy vs. Renewable Energy*, ii) *Space Exploration*, iii) *Biotechnology*, iv) *Nanotechnology* and v) *Access to Internet and Development*. Additionally, there are fourteen more educational packages written in English by the other participant countries for further debating practice.

The pre-mentioned educational material is based upon the "Students' educational worksheets", that is an educational package which reveals to students:

a. the importance of data and evidence in the scientific field for decision making and decision taking through examples, models, histories etc.,
b. the existence of scientific theories which are not still well-established or core explanatory theories due to the lack of substantial evidence or because of the presentation of controversial evidence and counter-examples,
c. the position of science within the wider social community and its influence on it,
d. the importance of the scientific argumentative process aiming at teasing out "as much information and understandings from the situation under discussion as possible" due to the use of logical and alternative scientific points of view (Duschl et al. 2007, 32).

In particular, each educational package is composed by:

a. definitions of the necessary scientific notions for the comprehension of each topic, since the scientific terminology is often odd or unfamiliar to students, or common words often hide specific meanings which are different from their everyday use (Asimov 1959).
b. Introductory questions on the topic after the presentation of a relative powerpoint to the students by an expert or the responsible teacher.
c. List of students' initial arguments classified into three categories: i) in favor of the resolution, ii) against the resolution and iii) arguments that can be used by both sides insinuating that scientific ideas can't be completely accepted or rejected *ad hoc.*
d. A series of 10-16 cards of facts or events concerning the examined issue that provide evidence for or against the resolution.
e. A series of 8-10 story cards that include interesting, strange, humoristic stories about each scientific issue revealing further (for and against) information about it.

f. A series of 10-12 question cards that intend to deepen and consolidate the students' knowledge on the examined topic after the study of the educational material.
g. Controversy plan: students write in columns three arguments for or against the topic according to the following format: i) arguments, ii) probable counterarguments addressed by the opposite team and iii) response to counter-arguments.

As it becomes obvious, the educational packages intend to facilitate students acquire sufficient understanding and knowledge on the topic both from the body material as well as from the process of questioning and responding before the implementation of the debates. In this way, students learn about important scientific facts that can be used for constructing their arguments on the examined topic, while the evaluation and use of the appropriate evidence can further support their written arguments. In more, the research of arguments and probable counterarguments extends students' way of thinking, since they are called to acknowledge that there are various interpretations of the same scientific topic. In other words, the project, from the beginning, inducts students into scientific argumentation based upon evidence-explanations (Osborne 2014; Berland et al. 2016).

After the completion of the above process, students participate as researchers-debaters to the realization of the scientific debate *Odyssey* in classroom. At the end of the testing phase, in each partner country, a competition among the participant schools follows. In Greece, because of the pandemic COVID-19, the preliminary rounds of *Odyssey* Debates were organized on-line the 10th of June 2020 with the participation of 11 schools, as already mentioned.

The two winning teams in each country will participate to the final debate contest during the dissemination phase of the project (September 2020 until March 2021) within the context of a national conference which will permit the presentation of the experiences gathered by the participant schools and the discussion of the role of the debate in STEM education. Also, workshops for teachers will be realized in order to get acquainted with the materials of the project.

Within this context, the implementation of the scientific debate *Odyssey* is considered as a discursive scientific arena that validates science as process and contributes to its understanding (National Research Council 1996, 23). In parallel, students get familiarized with the idea that "Science is an activity of human beings acting and interacting, thus a social activity" (Mendelsohn 1977, 3), while they actively participate to the process of the social construction of the scientific knowledge.

Participant students are called as debaters-researchers to explain the examined issue through their argumentation, to provide appropriate evidence for supporting their arguments, to exchange arguments, to ask questions in order to better understand the topic. At the same time, as audience, they have the chance to evaluate the provided arguments voting for the more convincing scientific argumentation, even contrary to their initial personal opinions on the topic, extending or changing their conceptual structures.

3. Presentation of Odyssey Scientific Debate

The *Odyssey*-Scientific Debate represents an interactive scientific team event that advocates or rejects a scientific position about a controversial scientific topic after the conduct of a thorough inquiry on it (Freeley and Steinberg 2009, 3) in equal and adequate time for both research teams (pro- and con-). The event takes place in front of a layperson audience through the exchange of arguments between students. The chosen format permits students to cultivate their argumentative, communication and critical skills by sharing effectively their scientific knowledge on STEM topics with their peer-mates during the debate, facilitating "genuine episodes of learning themselves" (Wolf 1993, 213).

The format of *Odyssey* scientific debate is inspired both by: a) Oxford Debates and b) Public Forum Debates (National Forensic League 2009). It is presented in two variations: a) the Classroom Format (CLA.F.) and b) the Contest Format (CON.F.). The first variation (CLA.F.) lasts forty-five minutes (45') and is responding to the limitations of time within the school-context, while the second variation (CON.F.) lasts approximately eighty-two to ninety minutes (82'-90') (Egglezou 2019).

The factors that influenced the development of the *Odyssey* scientific debate format were:

a. The participation of the audience.
b. The thorough examination of the controversial topic.
c. The invention and use of high-quality arguments and counter-arguments.

Concerning the participation of the audience, it is considered essential and necessary in both variations. The audience has the right, first, to an initial vote revealing its prior opinions on the topic and, second, to a final vote in the end of the debate. The final vote declares the winning team only within the CLA.F. context, while it might reveal if any conceptual changes have occurred. Within the CON.F. context, the audience maintains the right to an initial and final vote, but the final winning team is declared by the Judging Scientific Committee which is composed of three judges. The judges are expert on science issues, scientists and educators. The judging committee poses at least one question to the first two researchers-debaters of each research-team. If time remains, the format allows the energetic participation of the audience through the posing of more questions on the first and second researcher-debater of both research-teams.

As regards the second factor, the thorough examination of each topic is considered very important, as *Odyssey*-scientific debate puts emphasis to the acquisition and sharing of knowledge for the successful support of the evidence-based argumentation. For this reason, debaters must: a) conduct and demonstrate a thorough research, b) use reliable sources, c) cite their sources during the debates, d) perform deep understanding of the topic, quality of evidence and persuasiveness. In the same line, the successful delivery of the produced argumentation must be characterized by clarity, eloquence, textual organization, cohesion, and logic.

As in any debate, the Odyssey-scientific debate is implemented by two research-teams: a) a proposition research-team (for the resolution), and b) an opposition research-team (against the resolution). The duty of the proposition research-team side is to support the truth of the resolution, while the opposition research-team has to refute it for supporting its truth.

Correspondingly, the speakers of each research-team are called researchers-debaters. They conduct an organized and systematic investigation for inventing appropriate and sound arguments that support their case and for successfully communicating them to the audience. For practical reasons, each research-team is composed of three (3) researchers-debaters instead of two (vs. Public Forum Debate format). Within the context of *Odyssey*, it is not guaranteed that the first constructive speech (C.S.) is the affirmative one, since the toss of a coin determines which will talk first. The first debater-researcher (1st round) is responsible for constructing the case and advancing the more important arguments of the research-team (constructive speech / 4' – 5'). The second one (2nd round) is responsible for refuting the opposite arguments and advance more the thesis of her/his own research-team (rebuttal speech / 4′-5′).

The third player talks twice (rounds 3 and 4) and he/she is responsible for the summary rebuttal (2′-3′) and the final focus rebuttal (2′-3′). The summary rebuttal consists of a demanding synoptic speech, where counter-arguments are refuted, the defense of the case is reinforced, the main arguments of the team are extended by providing only new evidence while the conclusion is deduced.

The final focus rebuttal aims at persuading the audience and the Judging Scientific Committee of the winning of the one research-team and the defeat of the other using defensive, offensive or mixed strategies (Fedrizzi and Ellis 2011). The speaker emphasizes why his team won, why the other team lost or he/she compares the argumentation of both research-teams ending up with the argumentative prominence of his/her own research-team. In this final speech the communication skills of the speaker are important as the main goal is the persuasion of the audience.

Another interesting part of the debating process is the interference of the discrete parts of questions and answers among the researchers-debaters, called cross-fire. Two cross-fires occur after the completion of the first and the second round between the correspondent researchers-debaters that last 3′ minutes as well as a grand cross-fire after the completion of the summary rebuttal among the first two researchers-debaters of each team. The third player doesn't participate as he prepares his final rebuttal.

The cross-fire parts of the debate are very important as students are called to exhibit their critical thinking skills. More precisely, the researchers-debaters stand in front of the audience or/and the Judging Scientific Committee and face them, while they keep an eye-contact with the audience. So, the judges can compare their performance in equal terms. During the exchange of questions and answers, on the one hand students are called:

1. to submit purposeful, brief, focused and simple questions,
2. to clarify obscure points of ideas, arguments or evidence of the opposite research team,

3. to reveal weak argumentative points of the opposite team,
4. to establish an idea or argument before its introduction to a speech (Hannan et al. 2012, 102).

On the other hand, their answers have to be short, substantial, honest, focused and relative to the question. During the cross-fire the ethos of the debaters-researchers has to be shown as well as their respect towards the opponents.

The goal of *Odyssey* scientific debate is dual: a) to convince the audience of the scientific validity of their position (CLA.F. and CON.F.) and be voted by the audience and b) to convince the Judging Scientific Committee of the validity of their position in order to gain its recognition. In other words, the goal of each research-team is to gain both the prize of the audience as well as the prize of the Judging Scientific Committee that determines the winning research-team.

The resolution(s) of the contest is/are chosen by the organizing committee of the contest approximately twenty minutes (20′) before its opening. The Greek resolutions are the following: i.a) *Biotechnology is the enemy of human health* and i.b) *The environment will benefit from the advances of agricultural biotechnology,* ii) *The future of humanity depends on space exploration,* iii) *Exploiting nuclear power is the only solution to meet the energy problem*, iv) *The use of nanomaterials causes severe health problems* and v) *Global internet access can be achieved only through wireless networking.*

All the above are fact resolutions, since they «just make statement about reality» (Abell 2018, para. 5). They demand the use of factual arguments, related to logic and evidence for supporting the thesis in order to prove the soundness of each argumentative position. In this case, the debaters are called to use the Aristotelian "non-artistic" means of persuasion (Aristotle 1995) such as statistics, laws of science etc. as evidence.

Undoubtedly, other topics belong to the category of *policy resolutions,* where the researchers-debaters propose a specific action or reveal the consequences of a future modification. For example: *In mid-latitudes we should invest in solar energy production*. Finally, there are value resolutions, since the researchers-debaters make scientific judgment on a certain issue (e.g. the efficiency of a scientific method). In this case, the criteria that apply to the judgment must be set (Erickson et al. 2003, 7). For example: *In mountainous catchments, hydrotechnical solutions are more efficient for flood protection than nature-based solutions* (value resolution).

The assessment of the participant research teams by the Scientific Judging Committee is based upon the following criteria (O3 Methodological Guide Odyssey 2019):

1. Argumentation skills:
   a. Quality of Arguments
   b. Rebuttal Arguments and Refutation
2. Quality of Scientific Evidence
3. Debating Skills: Methodology
4. Communication skills
5. Linguistic skills: Use of Language / Structure of speech

6. Teamwork
7. Dialogic/Critical skills
   a. Quality of questions posed
   b. Quality of answers

4. The implementation of Odyssey at the testing phase: Data and methodological framework

4.1 Purpose

The purpose of *Odyssey* was the improvement of students' skills in: a) reasoning in STEM, b) communication in the mother tongue, c) argumentation, d) public presentation, e) giving statements consistent with the language culture, f) promote the analysis and interpretation of scientific data, and g) the increasement of their interest in STEM education (e.g. Chemistry, Physics, Biology etc.) through the introduction of debating scientific issues.

4.2 Participants

In total, eleven (11) schools participated to *Odyssey* and accomplished the testing phase of the project. Eight (8) of the participant schools were public (72,72%), while the rest of them were private (27,27%). In more, nine (9) of the participant schools were Lyceums (≈82%) (Upper Secondary Schools for students from 16-18 years old), while two (2) schools were Gymnasiums (Junior High Schools for students from 13-15 years old). Ten (10) of the participants schools were located in various urban zones of Athens, while one (1) was located in the country town of Lamia.

In total, 126 Greek students participated to the implementation of the project. According to their age, twenty-six (n=26) of them were 13-15 years old (20,62%), studying in public Gumnasiums/ Junior High Schools, while one hundred students (n=100) were 16-18 years old (79,36%) studying in public and private Lyceums / Upper High Schools [Fig. 1].

According to their sex, the majority (58,73%) of the participant students were females (n=74), while the males were fifty-two (52) (41,26%). [Fig. 2].

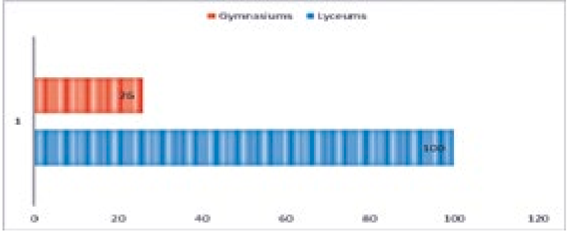

Fig. 1. Participant students to 'Odyssey' (Gymnasium vs. Lyceum).

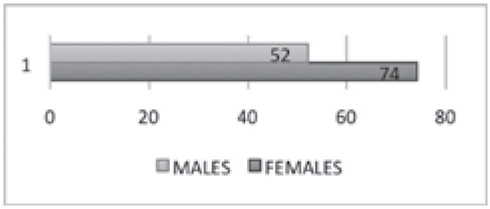

Fig. 2. Participant students to 'Odyssey' (males/females).

The project *Odyssey* was implemented either exclusively by STEM educators (in seven/7 schools) (individually or by groups of STEM educators) or by the collaboration of STEM educators with other teachers, mainly of Language Arts, specialized in the debates training (in four/4 schools). In total, twenty-three (n=23) educators were involved to the implementation of the project: eighteen (n=18) STEM educators (78%) and five (n=5) educators of other disciplines (22%) [Fig. 3]. In each participant school, one of the STEM educators was designated as responsible educator for monitoring the students' course during the implementation of the project *Odyssey*.

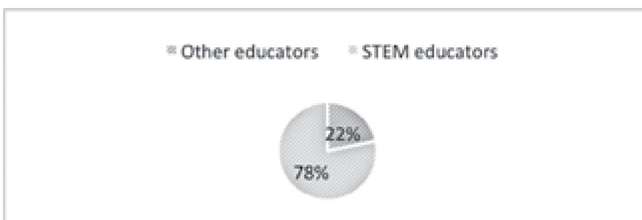

Fig. 3. Educators involved to the implementation of the project 'Odyssey'.

Among the participant STEM educators, thirteen (n=13) were females (72%), while five (n=5) were males (28%). The STEM educators belonged to the following scientific fields: Chemistry (n=5), Biology (n=4) Mathematics (n=4), Physics (n=4) and Informatics (n=1) [Fig. 4].

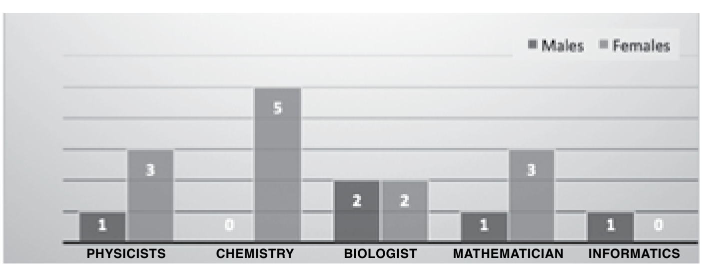

Fig. 4. Taxonomy of the participant STEM educators in "Odyssey".

4.3 Procedure

The project *Odyssey* was carried out from October 2019 until the 10th of June 2020, once a week. Only three schools (3) (27,27%) implemented it during the hours of STEM teaching. The other eight (8) participant schools (72,72%) implemented it after the completion of the compulsory daily program within the framework of scientific and rhetorical school clubs that function in optional terms within Greek Junior High Schools (Gymnasiums) and Upper High Schools (Lyceums). During the period from 12th of March 2020 until 10th of May 2020, as Greek schools remained closed due to the spread of COVID-19, the implementation of the project was interrupted.

Regarding the procedure, after the organization of the on-line debates *Odyssey*, the 18 participant STEM educators were asked "What were the greatest barriers you faced in introducing debates in the classroom?", Their responses to the pre-mentioned multiple choice question highlighted the following barriers: first, 83,33% of the participant STEM educators responded that the insufficient time consisted the main barrier for the introduction of debates in classroom (n=15). Secondly, 22,2% of the participant STEM educators noticed that, equally, the pandemic of COVID-19 (n=4), the difficulty of the scientific material (n=4) and STEM educator's insufficient prior experience on debating (n=4) consisted of further barriers in the introduction of classroom debating. For 16,66% of the participant STEM educators the students' fear of public speech (n=3) was an additional barrier, while 5,5% of the participants either considered that the benefits of using debates in classroom were unclear (n=1) or he/she wasn't sure how to find such project/materials that could be used in classroom (n=1). Finally, for the 11,11% of the participant STEM educators no problems were noticed during the introduction of classroom debates [Fig. 5].

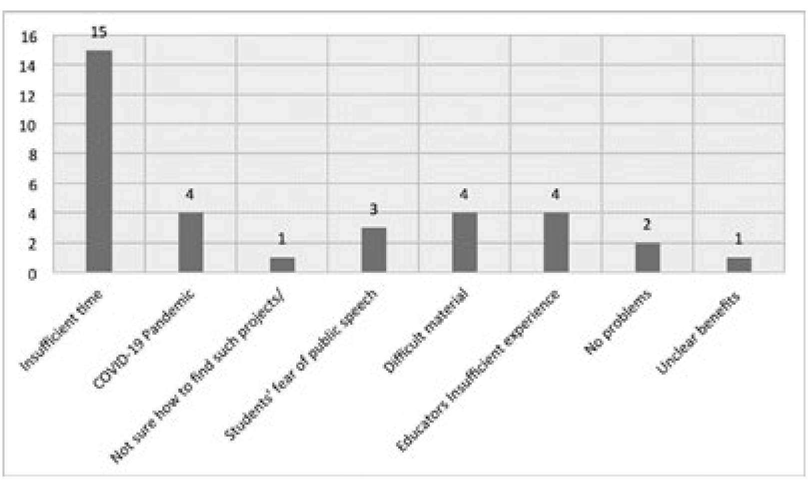

Fig. 5. "What were the greatest barriers you faced in introducing debates in the classroom?".

4.4 Data source and analysis

The corpus of the following data makes part of a broader pre- and post- survey to which eleven (11) STEM educators (one from each participant school), responsible for the implementation of *Odyssey* and the monitoring of their 126 students' learning course, responded. The pre-survey was given to the educators in the beginning of the implementation of the project, while the post-survey was responded after the organization of the on-line debates *Odyssey*. For the statistical analysis of the provided data the software package SPSS (Statistical Package for the Social Sciences) was used. The statistical analysis of data was based upon the assessment of the educators perceptions concerning their students' skills before (pre) and after (post) the implementation of the project in: a) reasoning in STEM, b) communication in mother tongue, c) argumentation, d) public presentation, e) giving statements consistent with the language culture, f) analysis and interpretations of texts/data/materials as well as g) their interest in STEM education.

For the analysis of educators' responses concerning their students' prementioned skills acquisition and their interest in STEM education, the psychometric tool Likert Scale was used for capturing "the attributes of human behavior and performance" and transforming it "into an objective reality" (Joshi et al. 2015, 397). More specifically, a variation of 5point Likert-scale with six ordered response options was used.

Despite the debate concerning the analysis of Likert Scales (Göb et al. 2007, 602), the parametric Paired Sample- T-test was used for analyzing the provided data, since cardinal statistics have already successfully been applied in the analysis of surveys that include ordinal data (Göb et al. 2007, 609). In this vein, Winter and Dodou (2010) support, that T-test has analogous statistical power to the Mann-Whitney-Wilcoxon (MWW) (p. 1) which is a non-parametric test, while Norman (2010) accentuates the "robustness of parametric tests" (Göb et al. 2007, 626) that ensure the right answer. So, the quantitative results of the pre- and post- surveys of the participant educators concerning their students' skills were analyzed in terms of descriptive and inferential statistics (Gillham 2000, 80; 86).

The reliability of the measurements identified for the analysis was checked by calculating Alpha Cronbach, which is indicated for the development of scales intended to measure "attitudes" as well as "students' knowledge" in science education studies (Taber 2017, 1275). Alpha Cronbach value of 0,992 was obtained for all the fourteen (14) pre- and post- examined items (seven/7 pairs of answers). Therefore, there was evidence that the internal statistical analysis of the data was reliable.

4.4.1 Quantitative results

First, the responses of the eleven (11) participant educators to the 6point Likert Scale of the pre- and post- survey concerning their 126 students' skills and interest in STEM education were collected and classified to the six ordered response options. The response options for each examined skill were numbered from 1 to 6: 1=*Very Low*, 2=*Low*, 3=*Rather Low*, 4=*Rather Good/High*, 5=*Good/High*, 6=*Very Good/High*. In more, the eleven (11) participant STEM educators had to indicate the number of their pupils that were classified in the six ordered response options. So, the provided data are 6point Likert Scale data for two groups (pre- and post-survey).

The Table 1, shows the categorization of students in the pre- and post-survey according to the examined skills and their interest in STEM education before and after the implementation of the project. The total responses of the 11 STEM educators are also presented in Figure 6.

Table 1. Frequency of students skills and interest in STEM education before and after the implementation of Odyssey.

Skills	Very Low	Low	Rather Low	Rather Good/High	Good	Very Good	Total
Reasoning in STEM (post)	1	9	35	39	29	13	126
Reasoning in STEM (pre)	7	39	37	29	9	5	126
Communication in mother tongue (post)	0	2	22	47	30	25	126
Communication in mother tongue (pre)	0	4	37	53	25	7	126
Argumentation (post)	0	5	42	43	27	9	126
Argumentation (pre)	4	33	50	30	8	1	126
Public presentation (post)	2	6	28	43	30	17	126
Public presentation (pre)	3	22	47	34	16	4	126
Giving statements consistent with the language culture (post)	0	7	39	31	33	16	126
Giving statements consistent with the language culture (pre)	2	16	51	39	12	6	126
Analysis and interpretations of texts/data/materials (post)	0	17	17	38	31	23	126
Analysis and interpretations of texts/data/materials (pre)	10	14	38	37	19	8	126
Interest of students in STEM education (post)	2	3	6	22	66	27	126
Interest of students in STEM education (pre)	5	13	30	25	42	11	126

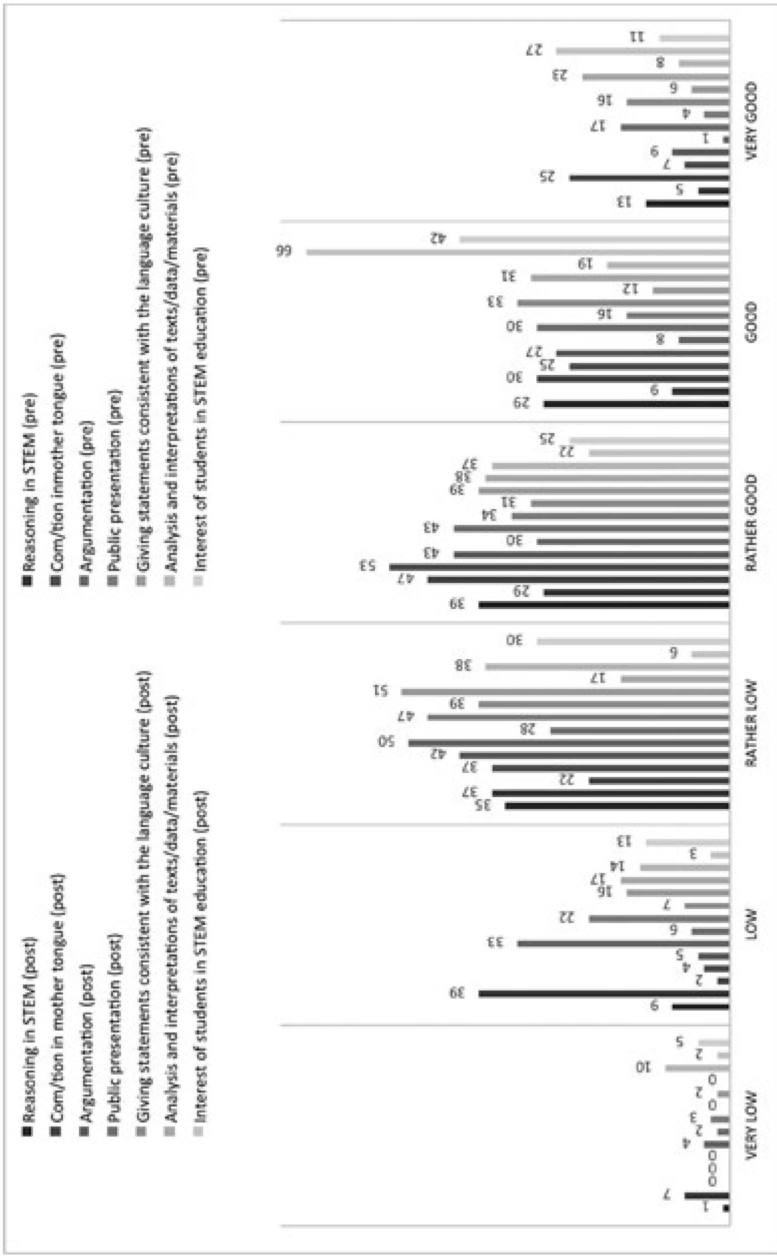

Fig. 6. Presentation of the STEM educators' responses to the pre- and post- survey concerning their students' skills and interest in STE.

The Paired Sample T-test, which analyzes the results referring to the same group of students, was used for the further statistical analysis of the responses of the eleven (11) STEM educators concerning their students' (N=126) skill *Reasoning in STEM*. The data obtained from the post-and the pre- survey indicated that the mean score of this skill increased significantly from M=3,0714 (SD=1,13487) to M=3,9921 (SD=1,18780) producing a bilateral significance (p=,000<0,005) for a confidence level of 95%. [See Fig. 7 and 8]. In more, it was shown that the Pearson Correlation coefficient between the reasoning in STEM pre- and post- was high (r=0,962)

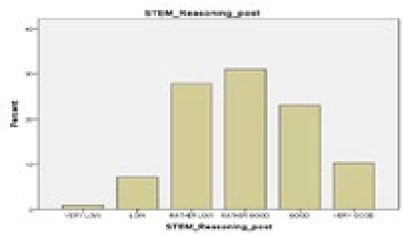

Fig. 7. Reasoning in STEM skill (post).

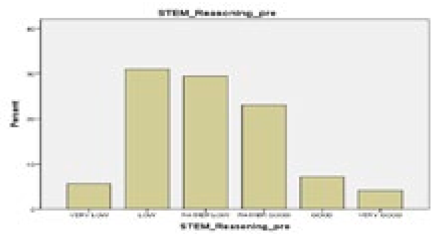

Fig. 8. Reasoning in STEM skill (pre).

As regards the students' skill *Communication in mother tongue* the statistical analysis revealed a significant difference between the mean score of the pre-survey M= 3,9524 (SD=0,91963) and the post-survey M=4,4286 (SD=1,04635). The statistical control attested to a bilateral significance (p=,000<0,05) in favor of the post results for a confidence level of 95%. [See Figures 9 and 10].

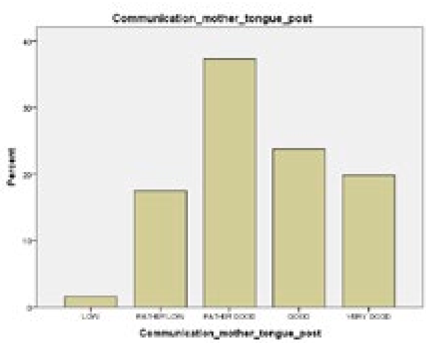

Fig. 9. Communication in mother tongue (post survey).

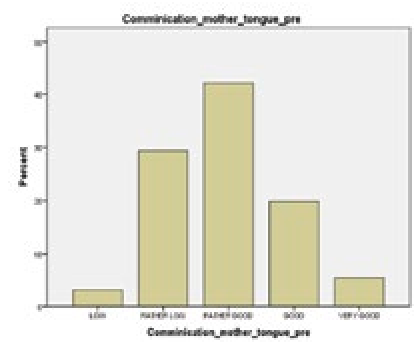

Fig. 10. Communication in mother tongue (pre-survey).

With regards to the students' skill in *Argumentation,* the mean score M=3,94444 (SD=0,99844) of the post survey was significantly higher that the mean score M=3,0635 (SD=0,97772) of the pre-survey. The statistical control noticed a bilateral significance (p=,000<0,05) in favor of the post results for a confidence level of 95%. [See Figures 11 and 12]. Additionally, it was shown that the Pearson Correlation coefficient for the *Argumentation* skill (pre- and post-) was high (r=0,946).

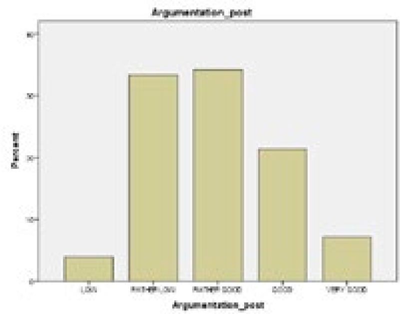

Fig. 11. Argumentation skill (post).

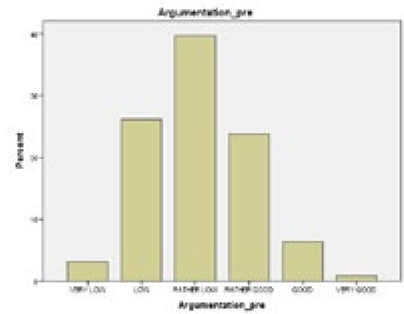

Fig. 12. Argumentation skill (pre).

Analogous results of bilateral significance (p=,000<0,05) for a confidence level of 95% were also noticed concerning the skill of students in *Public Presentation*. The mean score of the pre-survey M=3,3968 (SD=1,08870) was lower than the mean score M=4,1429 (SD=1,15040) of the post-survey. (p=,000<0,05, Confidence Level 95%).

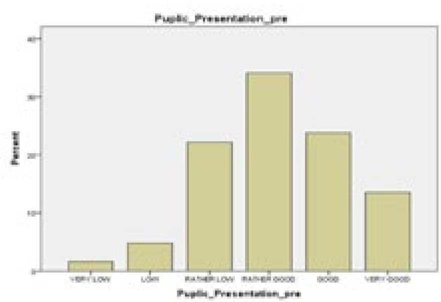

Fig. 13. Public Presentation skill (post survey).

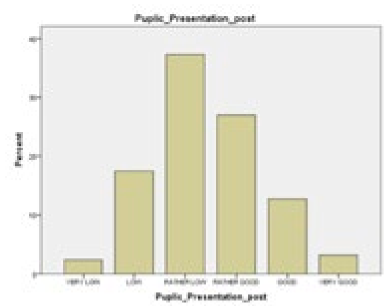

Fig. 14. Public Presentation Skill (pre-survey).

In the same vein, concerning the students' skill of *Giving statements consistent with the language culture* the mean score of the post-survey M=4,0952 (SD=1,14143) was significantly higher than the mean score of the pre-survey (SD=1,04103). (p=,000<0,05, Confidence Level 95%).

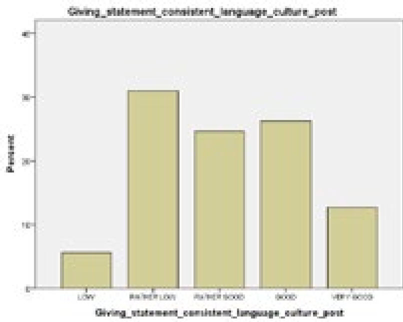

Fig. 15. Giving statements (post-survey).

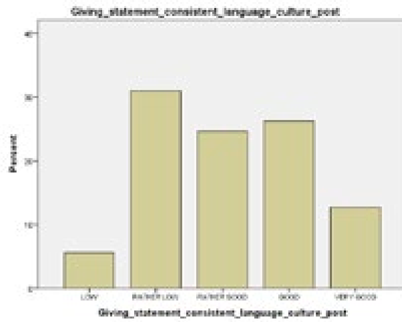

Fig. 16. Giving statements (pre-survey).

In more, the analysis of the results regarding the students' skill in *Analysis and interpretation of texts/data/materials* showed that the mean score of the post survey M=4,2063 (SD=1,27322) was significantly higher than the man score of the pre-survey M=3,5159 (SD=1,28209). (p=,000<0,05, Confidence Level 95%). In more, it was shown that the Pearson Correlation coefficient between the skill of analyzing and interpreting data/texts/materials (pre- and post) was high (r=0,934).

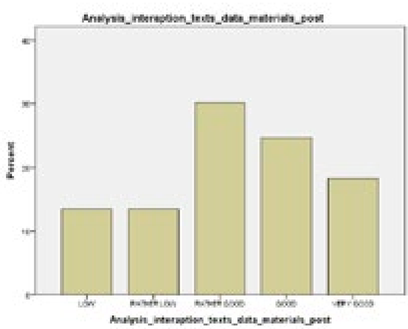

Fig. 17. Analysis and Interpretation of data (post).

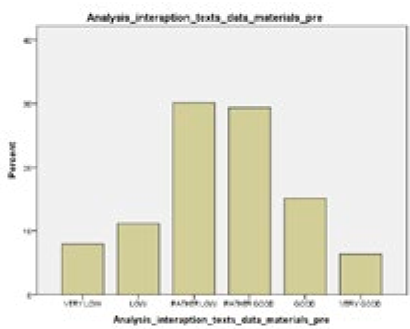

Fig. 18. Analysis and interpretation of data (pre).

Finally, the responses of the STEM educators in the post-survey revealed their students' interest in STEM education was significantly increased, since the mean score M=4,8095 (SD=1,00967) was higher than the mean score of the pre-survey M=3,9444 (SD=1,30418).

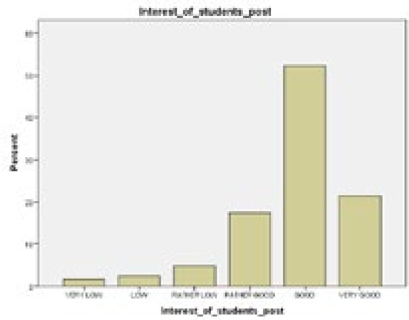

Fig. 19. Interest of students (post).

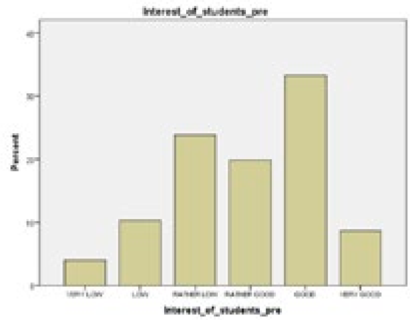

Fig. 20. Interest of students (pre-).

5. Discussion-Conclusions

The quantitative results presented in the previous figures and tables make part of the broader European Erasmus+ KA2 research project *Odyssey* and indicate the results of the implementation of scientific debates in the Greek school practice of STEM education. As it was revealed, the provided results were encouranging, since the 126 Greek students of secondary school that participated to the testing phase of the project, seemed to improve their skills in: a) reasoning in STEM, b) communication in mother tongue, c) argumentation, d) public presentation, e) giving statements consistent with the language culture, f) analysis and interpretations of texts/data/materials, while g) their interest in STEM education was increased.

These results were encouraging, because the spread of COVID-19 influenced negatively the development of the project, as Greek schools remained closed for, at least, two months (from 12th of March 2020 until 10th of May 2020). As a result, the energetic participation of the schools was interrupted. Schools couldn't organize live friendly debates among them as they used to in their attempt to apply the rhetorical turn in the teaching of STEM. In more, only three of the five scientific issues were fully examined because of the limited disponible time. Finally, the organization of the preliminary rounds of the debating contest on the 10th of June 2020 had to be organized on-line due to the prohibitive measures of social distancing.

Additionally, the responses of the eleven STEM educators regarding the implementation of the project in school practice revealed, among others, one serious barrier to their effort: insufficient time. The strict Curriculum of the Greek school seemed to discourage the implementation of the project within the compulsory program of STEM education in secondary schools. The majority of the participant schools get acquainted with the debating practice within the context of rhetorical and scientific school clubs that function in optional basis.

Other barriers that were highlighted by the participant STEM educators were the difficulty of the scientific material, the educators' insufficient prior knowledge on debating as well as students' fear of public speech. Such barriers indicate that the attempt to introduce scientific debates in school practice is a demanding and complex process which needs the examination of many parameters as well as the support of the institutional school setting of the Greek secondary education.

The main reason for advancing such a proposal is, as the initial quantitative findings of our research confirm, that scientific debates tend to promote students' scientific literacy and to develop life skills both for the involved students and STEM educators. On the one hand, such results add to the broader educational research regarding the debate technique as teaching strategy (Williams-Brown 2015; Baso 2016) in school practice. On the other hand, the positive initial results of our research indicate that such educational efforts might contribute to the formation of better 'STEM prepared workers and educators around the world" (Kennedy and Odell 2014, 247), capable of affronting the challenges of the 21st century as global democratic citizens.

Undoubtedly, the initial quantitative results of our research have to be further elaborated. In particular, they have to be related to the results of the other participant countries in order to form a clearer idea of the whole influence of the project. In more, the quantitative analysis of data has to be completed with the qualitative analysis of students' arguments as well as with the analysis of their attitudes towards the implementation of the project. In more, different parts of the pre- and post-survey have to be analyzed in order to reveal the impact of *Odyssey* to the involved STEM educators as professionals. As it becomes clear, the *Odyssey* trip has just started creating multiple areas of prospective studies and researches.

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