American Journal of Educational Research, 2015, Vol. 3, No. 12, 1618-1628
Available online at http://pubs.sciepub.com/education/3/12/20

DOI:10.12691/education-3-12-20

Applying Argumentation Approach in STEM Education: A Case Study of the European Student Parliaments Project in Greece

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Abstract Although, worldwide, it is claimed a pressing need in ensuring that students are adequately equipped with the right skills to tackle the serious challenges that lay before them, there seems to be a failure in the empirical implementation of the national curricula to meet this goal. STEM courses are provided to students in the form of an authoritative discourse that leaves no room for students' development of critical, creative, problem-solving and reflective analytical skills. In this research study we explore the argumentation approach and its implementation in an authentic scientific inquiry context as a way of enhancing students' skills and promoting their construction of knowledge. Towards this aim, we investigate the case study of the European Student Parliaments project in Greece which sets a collaborative learning environment for the implementation of the argumentation approach. This paper will discuss findings from the implementation of the project and elaborate on the required conditions for its realization and efficiency in enabling students to become engaged in the negotiation of authentic scientific issues/problems by providing and sharing multiple alternative perspectives for their solution. Towards our research aims we have registered students' scientific arguments and we provide findings from the questionnaire that was used as a research tool to identify the efficiency and impact of the approach in enhancing students' knowledge construction and shaping their attitude towards STEM courses. The research findings have given us an insight into the significance of having students engaged in collectives in meaningful challenges that address authentic issues relevant to their lives. The implementation of collaborative discourse involving arguing from evidence, following the authentic scientific inquiry process, can enhance students' acquisition of life-long skills and construction of scientific knowledge and meaning generation and motivate them to further engage in the negotiation of scientific issues.

Keywords: *argumentation approach, challenge-based learning, collaborative discourse, inquiry process*

Cite This Article: Zacharoula Smyrnaiou, Evangelia Petropoulou, and Menelaos Sotiriou, "Applying Argumentation Approach in STEM Education: A Case Study of the European Student Parliaments Project in Greece." *American Journal of Educational Research*, vol. 3, no. 12 (2015): 1618-1628. doi: 10.12691/education-3-12-20.

1. Introduction

The argumentation approach accommodates the scientific community and its epistemic practices as a key point in delivering scientific inquiry [4,33] aiming at the reinforcement of knowledge, the production of new knowledge and validation of new ideas and findings [18]. Argumentation plays a central role in the construction of scientific theories and providing explanations [21] as scientists use arguments to link and juxtapose the claims they make through use of warrants and backings [43]. As a result, it would be reasonable to assume that this approach should also govern and guide relevant scientific educational courses. However, little research has been carried out on the role of argumentative interactions in collaborative learning in STEM courses. Instead, STEM courses are characterized by persistence in authoritative discourse [28] where students simply read in their textbooks or listen to their teacher present them scientific ideas and their supporting evidence. Therefore, they are confronted with de-contextualised and fragmented knowledge, deprived of any personal motivation for knowledge construction and engagement.

However, engaging students in argumentation processes provides them with a better insight into the nature of scientific enquiry and the ways in which scientists work. This enculturation in the scientific discourse [8,9] can subsequently lead to epistemic improvement in pupils' knowledge [1]. The implementation of such a natural and scientific approach allows students to engage in processes that will bring into the foreground their own conceptualizations and ideas regarding scientific ideas. This approach implies a turn of focus from 'what' we know to 'how' we know it, enhancing students' construction of knowledge. Students are inevitably committed to principles such as evidence and rationality in order to justify their knowledge claims with evidence [23,38]. Collaborative learning in the form of argumentative discourse is an empowering interactive learning mechanism in which students engage cognitively in potentially conceptual transformations [40,42] and 'constructive interactions' in their effort to reach consensus in a collaborative search for truth [25].

In this paper our main objective is to explore the effectiveness of the argumentation/debate approach in enhancing students' creative eliciting of multiple alternative perspectives and knowledge construction and the impact factor of the approach in shaping their attitude towards STEM courses. Towards this aim we have investigated the case study of the EUSP (European Student Parliaments) project in Greece which encompasses adequate features in terms of authentic context and content of a learning environment that can accommodate and promote the argumentation approach. The project's main aim is "to strengthen the dialogue and exchange of ideas between students and scientists, introduce students to parliamentary procedures on science and research, enabling students to form a qualified opinion and to assess complex topics, and introduce students to a European community" [37].

In this research study we describe the learning environment and its organization as set in the EUSP in Greece and identify the guidelines and the way the scientific community supported the learning process. We also describe the way argumentation intervenes in STEM education as a teaching process in alignment with the learning goals. In the project the topics for negotiation were selected due to their challenging factor and their centrality to contemporary scientific issues and problems that need solving. It was identified that by immersing learners in active investigations of contemporary issues, and engaging them in collaborative discourse, they manage to constructively build on each other's ideas and enhance their learning of scientific concepts. We provide students' arguments as evidence for students' enhancement in meaning generation, construction of new knowledge and sharing of multiple alternative perspectives. In addition, a questionnaire was selected as a research tool to investigate the impact factor of the implemented learning approach in shaping students' attitude towards STEM courses. The questionnaire was developed by "Wissenschaft im Dialog" (http://www.wissenschaft-im-dialog.de/) in the context of the EUSP conduct. The findings from our research reveal high rates of positive stances towards scientific courses by engaging students in argumentative discourse and debate processes while negotiating authentic issues that bear strong relevance to their lives.

2. Theoretical Approach

Although argumentation consists a core feature that accommodates the epistemology of science, science education has failed to incorporate it in its didactics. The same way argument and critique are essential skills in the scientific community for the delivery of its main objectives –production of new knowledge and reinforcement and validation of ideas [29] – argumentation as an educational technique in science classes has been found to be tightly related to students' acquisition of scientific knowledge and enhancement in acquiring higher order skills related to problem-solving, scientific reasoning, communication capabilities and analytical thinking [34,36]. Research findings in science education have shown the importance of embedding the argumentation strategy in the educational process [8,9,19,26] and yet very few educational practices on a structured basis have been traced towards this goal [27]. However, the focus on the language of the science classroom could also give us an insight on the way teachers' use of language influences the pedagogy of science [39]. The significance of implementing argumentation in scientific courses is also depicted by a recent tendency to embed the argumentation approach in educational tools. Glass Lab in collaboration with NASA in its effort to design an educational game has embedded the notions of reason and argumentation in a video game which features a futuristic adventure story requiring decision taking grounded on sound arguments [13].

By excluding the element of argumentation –as a "dialectical approach" [2] -from the learning process of the science classes, we fail to instil in students the challenging aspect of scientific inquiry [22] and to enable them to develop a holistic view of the required process for the production of scientific knowledge and scientific discourse. These processes lie in the reinforcement of theoretical scientific assumptions and claims by providing relevant data and supportive arguments or even the refute of claims with counter-arguments. Argumentative interactions have the potential to lead to meaning generation [40,42] and enable knowledge to evolve, transforming initial ideas and intuitions into more refined and grounded concepts and knowledge, which may eventually be internalised [2]. Instead, students deprived of this scientific procedure, either verbally by the lack of argumentation language or practically by the absence of inquiry practices, perceive science as a ready to consume product and an authoritative and sterile field that allows for no challenging exploration. The reason of deprivation of science education from argumentation and debate educational practises lies in the one-dimensional delivery of science instruction, strongly focusing on the transmission of knowledge rather than on the individual engagement in the process of understanding and perceiving the way we came to acquire this knowledge; a fact that is also emphasized by the curricula and the authorized educational material that support science teaching. Therefore, there seems to be persistence in the fallible learning process of transmission of indisputable knowledge produced by experts.

In addition, students fail to face and clear up the misconceptions they have on scientific issues and concepts since ready-made and indisputable explanations offered by their teachers leave no room for scientific reasoning and construction of scientific knowledge based on the ground premises of mental exploration, testing hypotheses, data collection and consequent discursive exploration. Even if one assumes that these processes are mentally realised and there is no perceived purpose for them to be expressed verbally, research findings have shown the crucial role of collaborative discourse and the significance of discursive elaboration, justification and argumentation in both scientific meaning generation and construction of scientific knowledge [40,42]. It is through the students' effort to make their claims comprehensible and sound while addressing others that engages them in deep rationalization and construction of solid knowledge [15,35]. Learning derives as the product of the cognitive interaction and conflict between intuitive learning and new cognitive schemas and ideas that are structured by challenging our intuitions while engaged in situations in which we must provide data and arguments in order to support and strengthen our claims [41]. Students engaged in argumentative interactions will be required to step back from their claims, examine their proposals with respect to counter-arguments, reflect on their current domain knowledge or submerging experimentation evidence and come up with new ideas that will be inner-examined in terms of scientific accuracy and validity [11,15]. In this aspect, it becomes obvious that this learning model requires the implementation of inquiry-based approach which consists an authentic scientific practice [10]. Debates and collaborative discourse are valuable learning situations that enable students to undergo such a mental inquiry process where misconceptions can be tested and eliminated and suggestions and/or counter arguments by others facilitate the up-springing of new ideas, trigger more advanced claims and enhance individual engagement in the connection of claims with data [15,35].

However, although the positive aspects of students' engagement in situations that require collaborative discourse and argumentation have been identified and strongly supported by relevant researches and meta-analytical studies [7,41] it is not claimed that argumentation should be treated as an end in itself or grounded on vague conditions. Certain parameters and features guiding its methodology and procedural realisation are indispensable in assuring its contribution to effective learning. First of all, students should be instructed in the use of relevant language and the norms of social interaction [29] that guide the structuring of arguments in order to effectively communicate their ideas to their classmates. In addition, students should be instructed in applying the inquiry approach in their effort to formulate and correlate data with claims and arguments. These two learning processes are, however, not self-existent but tightly interrelated since they necessitate reciprocal 'feeding'. In other words, the application of argumentation language requires the identification and exploration of evidence as core elements in its structure and respectfully the identification of data necessitates the application of argumentation language which by structure is grounded on reasoning principles that lead to a clear outcome [5]. In addition, in the Inquiry-based learning model discussion/argumentation is a prerequisite, potentially present during the whole process (discussion in-action) or upon its completion in a reflective manner (discussion on-action) [30].

Argumentative interaction in its epistemological dimension [2] involves three aspects of knowledge: (1) the intrinsic properties of knowledge which involve alternative solutions or conceptual points of view due to its inherent ambiguity, (2) the knowledge domain which reflects and addresses the knowledge possessed by domain experts and (3) the source of the knowledge which involves the learner's attained current knowledge and the social-institutional status of the person from whom knowledge is acquired (eg, teacher, scientist, etc.). In addition, its conceptual dimension highlights mainly the construction of knowledge and evolution of ideas as triggered by clarification purposes (explicit elaboration on ideas) that entails deep cognitive access to the scientific issue under negotiation [41]. For example, learners while engaged in collectives in a problem-solving situation which requires a common resolution and agreement will be inevitably driven to extend, reject, transform initial proposals into new ones agreed upon and accepted by all members of the team as a satisfying and efficient solution to the problem they are dealing with.

Collaborative learning in the form of argumentative discourse produced in collaborative problem-solving situations is an empowering interactive learning mechanism in which students engage cognitively in potential conceptual transformations and 'constructive interactions' [2]. The communicative process undergoing the interactions between the learners produces a cognitive effect that requires intense student engagement in constructive thinking and application of analytical and critical skills [15,35]. Students are engaged in a joint attempt of mutual understanding through argumentation interactions [41] which act as filters of intuitions and misconceptions [29]. Students participating in these communicative interactions become committed and are driven by the main objective to appear reasonable –in alignment to background/reference knowledge on scientific domain and application of relative discourse and subsequent norms. By having students work in collectives to prepare for a debate process against other teams, engaged in a search of providing strong and rational-based claims, the scope of the communicative interactions becomes wider, involving persuasion, convincing, problem-solving and engagement in an in-depth knowledge co-construction process [15,16].

Peripheral but core parameter in students' engagement in such processes is also the aspect of challenge that characterises the content of the discourse. Students' personal needs and interests should always be considered in order to enhance students' mental engagement in the learning process. In addition, the context of the discursive exploration is a parameter that greatly affects students' motivation and engagement [5]. By context we refer to the informal learning approach during which students have the opportunity to experience more real life situations and make connections between the acquisition of scientific concepts and their pragmatic/realistic application. Challenge-based learning accommodates the conditions for engaging students in authentic issues and providing the adequate context for students themselves to do science rather than simply act under the demands of a science curriculum [17]. Socioscientific issues (SSI) [44] and inquiry-based approach grounded on challenge-based learning can serve as useful contexts for teaching and learning science content by enhancing the acquisition of specific content knowledge and understanding of the nature of science [31]. They raise questions of high complexity and are subject to ongoing inquiry [31], requiring for their negotiation, cognitive reasoning and reflective judgement [14,20]. In addition, SSI facilitates the development and elaboration of multiple, alternative perspectives while engaging students in argumentation processes [12,32]. Authentic context and activities not only highly motivate learners to acquire new knowledge [3] but they also provide a perspective for incorporating new knowledge into their existing knowledge and an opportunity to apply the newly acquired knowledge [10,32].

The EUSP brings in its agenda real world issues (eg. global warming, green house effect, stem cells, alternative ways for human reproduction, etc.) and scientific and technological topics of great social impact. Having students motivated by and engaged in authentic problems that require solving and stimulate their creativity and critical thinking they become key players of the learning process. Relevant studies that have addressed the issue of challenge-based learning reveal significant findings on the degree of students' engagement to creative solutions while dealing with topics which are critical for their own lives and surface the essential relevance and connection between the curriculum and their everyday life or future career [17]. In this highly motivating and challenging process, students acts as scientists and naturally apply inquiry–based approaches to address the problem under negotiation (Figure 1). They develop research questions, identify, investigate and experiment on various solutions with the help of primary source materials and construct knowledge and build their argumentation discourse in their effort to identify the most efficient and reasonable solution in terms of applicability. The guidance provided by scientific experts not only manages to relate the scientific research with educational environments but also to ensure a high-quality production of findings and to give the process relevance to authentic scientist way of working.

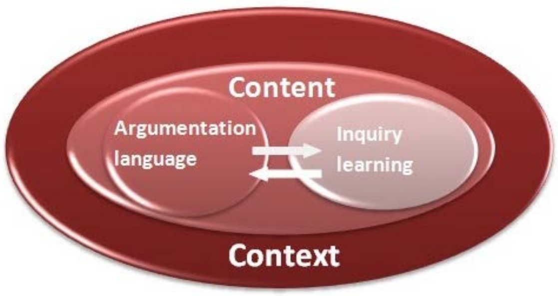


Figure 1. Schematization of the main features and underpinning learning processes governing the argumentation approach

3. Context of the Research Study-The project "European Student Parliaments"

Since 2001 Wissenschaft im Dialog ("Science in Dialogue") has organised scientific student parliaments as part of the Summer of Science (German Science Festival). Furthermore as part of the research project "Debate science" (2009 to 2011) the student parliament was thoroughly evaluated as an instrument of science communication. The results were very positive, thereby encouraging WiD to expand the concept. Based on these initiatives Wissenschaft im Dialog initiated in 2013-2014 the project "European Student Parliaments" (EUSP) (http://www.student-parliaments.eu/) that was funded by the Robert Bosch Foundation. EUPS aims at strengthening the dialogue between students and science throughout Europe, by engaging students in problem-solving situations involving scientific issues that address current problems. In the simulated parliaments, the participating students become acquainted with parliamentary decision-making processes as well as scientific research grounded on the model of Inquiry-based learning and develop life-long and communicative skills by engaging in dialogue and debate processes aiming at the exchange and sharing of scientific points of view. During the research phase and preparation for the locally held debate event, students are supported both by their teachers as well as a scientific expert. In the 2014 European Student Parliament, students' main topic of negotiation was "The future of our city". The project was addressed at students between 16 and 19 years old with interest in the functioning of democratic systems, science and learning about new topics and with ambitions to share their ideas in discussion [37].

In the context of the EUSP, approximately 2000 students from across Europe participated in 19 national parliaments In each of 19 local or national student parliaments, taking place from September 2013 to April 2014, 70 to 100 students participated and discussed five to seven subtopics in five working groups: (1) Future mobility – New approaches in the city, (2) Demography in the city, (3) City and climate change, (4) Energy efficient houses and flats and (5) Smart city: life in an urban network. One student per working group was selected to represent her/his subtopic at the final European student parliament, which was held during the Euroscience Open Forum Conference, in June 2014, in Copenhagen

3.1. Methodology of the Case Study - Athens (Local Student Parliament)

In 2014, Greece had taken part for the first time in the EUSP project. The project was locally organized by the Pedagogical Department of the National Kapodistrian University of Athens and the Science View Organization that promotes science communication activities between the scientific community and the wider public. Invitation for participation to the programme was realized through the Greek Ministry of Education and the final debate event was realized under its auspices. A significant number of schools had volunteered to participate from all over the country. However, due to the fact that the locally held debate would be realized in Athens, several schools had to withdraw their participation for practical reasons (eg. students' transportation to Athens, cost of transport expenses, etc.).

During the students' preparation phase, all participants were supported by experts in the specific fields that could share and exchange their ideas and communicate with the students and teachers. In addition, during the whole process of the Local Student Parliament, there were five researchers – one for each working group - who was responsible for tracking the group's working process and methodology and gathering and analysing data from the teachers' group progress reports.

Figure 2. Photo from the archive of Science View

Finally, in the debate event, held in Athens, 130 participants-students from 10 both public and private schools (9 schools were in Athens and 1 in Crete) took part in the European student parliament, discussing "The Future of Our City". The debate event lasted for three days, from 2-4 April, 2014, in Ellinogermaniki Agogi.

After an elaborate and remarkable preparation in their classes at school, the students were able to discuss the different sub-topics on a very high level and to express their ideas in the committee sessions with the scientists. In the plenary debate, the participants exchanged their knowledge with the other students and came up with some good final resolutions that will be presented in the following section. Finally, students were requested to answer a questionnaire expressing their views on the whole process for the debate event.

For the actual realization of the debate event, students were provided with specific guidelines for its procedure, following four successive steps: (1) Reading out the claims, (2) Defence speech, (3) Attack speech(es) and (4) Response to attack speech(es). Schools that had negotiated the same topic would have to discuss and decide on the final claims/resolutions that would comprise their final argumentation basis. First, at the beginning of each debate, the proposing committee had the opportunity to read out the committee's claims which were gathered in a structured resolution booklet template. Subsequently, the proposing committee had the opportunity to hold a defence speech and to explain the existing resolution and its contents. All committees were given the opportunity to hold one or more attack speeches to elaborate and explain why some of the claims should not be accepted by the delegates. Finally, the proposing committee had the opportunity to give answers to the attack speech and to allay doubts the delegates might have. The final open debate was structured in three procedural steps: (1) Open debate, (2) Summarising speech, response to last questions and (3) Voting. During the first procedural step, all members of all opposing committees (addressing all 5 subtopics) could raise their hands to address questions or remarks to the proposing committee which was required to give a summarising answer to all of them. In the second procedural step, the proposing committee would hold a summarising speech and answer the last questions and the third step involved having the chair of the debate read out the claims and ask all delegates to vote for or against a claim.

3.2. Elaboration of Students' Scientific Argumentation -Debate resolutions

For the subtopic "Future mobility, the participating schools discussed and assessed aspects and problems related to the current state of mobility issue. These include existing public transport, comfort/quality in public transport, infrastructure and the difficulty for someone to reach in time his/her destination, pollutants released by vehicles on the atmosphere, alternative energy sources, parking and pedestrians. In order to resolve the above issues, students claimed, first of all, an extensive public transport network, which would connect all areas of the city in order to reduce use of private vehicles. They also claimed fare payment with electronic boarding pass and use of new technological machines, (eg. GPS) at every transit station informing people about routes, timetables etc. A second resolution that students claimed was the use of alternative fuels. Upon investigation, they proposed use of alternative fuels, in all vehicles (private & public transport), such as liquefied petroleum gas, hydrogen (zero-emission fuel), biodiesel, biomass, solar energy etc. and alternative energy sources were proposed to be used to provide the transit stations with electricity (combined with conventional), considering the climatic and geomorphologic conditions of each city; for example solar energy, wind power etc. Addressing the issue of social vulnerable groups (eg. disabled, elderly and children) in terms of mobility, students claimed that public transport should be friendly to vulnerable groups by developing and applying adequate infrastructure. According to students, bicycles and pedestrians is a very important aspect of future mobility. Towards this aim they claimed creating urban networks which would be friendly to pedestrians, with green spaces, pedestrian main streets, and providing citizens with municipal bicycles. They also claimed the creation of stations all over the city where someone could take or leave his/her bicycle and the creation of an extensive network of bicycle paths. They also highlighted the reduction of car use in the city and particularly in the centre, by encouraging people to use other transports by providing as solutions the development of special parking places in each region, banning parking in central areas and financial relief and motives in the use of hybrid / e-cars. Finally they addressed the issue of citizen awareness through social media and campaigns and young people's road safety educational implementation in the curriculum.

"Demography in the city" was the second subtopic addressed by students. Issues that students researched and elaborated were the definition of the term demography, the historical background, the causes of demographic problem, the relationship between demography and financial, social, and political life of a country and the effects of welfare state crisis on demography. Furthermore, the issue of migration was also addressed concerning policies that should regulate mobilization considering specific country's needs, integration issues and infrastructure conditions for migrants' reception. In addition, the issue of brain drain and possible solutions was also discussed. Towards addressing the above issues the students claimed development of a common way (data base) of collecting demographic data, throughout Europe in order to promote social- demographic research. In addition, students highlighted the need for financial and health support and employment focused training for migrants.

Students negotiating the issue of "City and climate change" presented their research data regarding impact factors and issues. They focused on industry responsibility and our daily habits in terms of energy consumption as basic factors that affect climate change. Towards this aim they stressed the need for heavy legislation that would oblige industries to use more renewable and environmentally friendly sources of energy and improve their infrastructure by placing filters. They claimed storing carbon dioxide below ground so as not be released into the atmosphere as it is one of the most active greenhouse gases. Furthermore, they stressed the need for increasing mass transportation by creating bus lanes, greater timetable consistency, reduction in fares and the general implementation of the BRT (BUS RAPID TRANSPORT). They also suggested the development of bike lanes and reduction of vehicles in inner cities by introducing a ‘green ring’ limitation and/or free access only by vehicles using alternative means of combustion such as "green" gasoline. Another important issue that was raised was the promotion of alternative domestic energy consumption (eg. wind, solar, nuclear, energy producing waves and geothermal). It was claimed that green loans and financial relief could motivate citizens to convert their houses into bio-climate; with better insulation to maintain the temperature, stained in light colors to absorb less radiation and use energy class A devices. It was stressed that environmental experts’ contribution is required in order to change the current scenery of big European cities into more environmentally friendly spaces by restructuring them to comply with the environmental requirements of today. In addition, urban growth should be promoted and campaigns for raising citizens’ awareness on climate change factors, impact and solutions (eg. recycling and using electricity more wisely, etc.) should be conducted.

The subtopic ‘Energy efficient houses and flats’ engaged students in researching ways that could facilitate and enable already existing buildings to save energy. The students suggested converting an existing conventional house into an energy effective one with the use of traditional natural and energy resources, involving placements of shades, greenhouses and airways, replacement of windows and frames, adding insulation materials and passive systems outside the building or conversion of constructive components into passive, adding external shading devices and use and exploitation of local rocks. They also stressed the need for state assistance with relevant legislation in which the state could adopt a policy of motives adopted by municipalities for underground infrastructure of roads to melt ice, a 70% governmental grant for energy loans, tax allowance up to 300€ and providing subsidized banking programs. Finally, the students proposed the construction of floating energy effective houses or settlements in the shape of a hive and the application of mirror mechanisms to reflect the solar energy. This type of houses would use passive heating, by exploiting the temperature stability of the sea, but also active heating systems, by exploiting environmentally friendly energy sources, such as the sun, the wind and the sea waves. They also elaborated on the possibility for waste treatment and providing water from desalination. As for the mirror mechanisms, these would use a meteorological system to inform the direction of the mirrors and a sensor mechanism to change the direction of the mirrors and shades. These houses would not only have low-energy impact for the environment but they could also be used as tourist attractions and in this way they could contribute to the tourist development as well.

The last subtopic that was addressed was “Smart city: life in an urban network” and involved several issues such as road and city mobility, safety, environment, citizen’s social networking, health and e-shopping resolutions. Students’ resolution regarding health was the creation of a patient electronic record, such as a patient’s health booklet in compliance with the Privacy and Personal Information Act and the Hospital Ethics Committee and Health Authorities. Telemedicine was also claimed to be an efficient supply for patients in cases of minor treatment and when hospitalization is not required. Students also pointed out some solutions for the accessibility problems of the disabled, such as special sound and light signals which could be linked with the wheelchairs, sound signals and sensors in buses for descending ramps, and special routes for disabled. Furthermore, students suggested the creation of certified sites that would address practical issues that disabled people face, support and enable discussion forums between patients and physicians. Also, lifelong learning and social/state care was a point of great importance for students. For the public transportation issue, students claimed electronic signs at bus stops and navigators showing the routes and stops, in all languages. Electronic weather forecasts on subway, updates for possible problems and delays in routes and suggestions for detours, rechargeable cards (with automatic charging) instead of tickets, monitors in every station that will inform citizens about basic services, news and useful phone numbers. Finally, driving safety (rear screen, sensors, sound signals, pedestrian detection) are also some main student’s claims about public transportation. Furthermore, addressing the issue of parking facilities, students claimed the construction of underground parking places equipped with sensors for detecting the available parking slots (updated via relevant application) and providing the possibility to reserve online a parking slot. Regarding the environmental issue, students proposed promoting and raising public awareness on the issue of recycling, introducing smart bins equipped with barcodes for material recognition to facilitate recycling and they also proposed solutions regarding renewable energy resources such as introducing spots in the city with photovoltaic where everyone could charge his/her mobile phone.

3.3. Researcher’s Data Analysis

By analyzing the data gathered by the researchers who attended and registered the procedural steps for the preparation phase of the debate event, four common elements occurred: (1) setting preliminary goals for the research, (2) following an inquiry-based approach, (3) students’ applying constructive argumentation to address the strengths and weaknesses of their research progress, and (4) students’ enhancement for collaborative work. Students scaffolded by their teachers, set preliminary goals that would guide their scientific research. In their statements all working groups highlighted the importance of linking their research findings with real life situations and extending their exploration by proposing innovative and scientifically related solutions to the problems they had been assigned. The inquiry based scientific approach was a common element in all teachers’ working groups progress reports and evolved around 5 phases: 1) Question Eliciting or Hypotheses setting, 2) Assigning specific tasks for active investigation, 3) Combining data and research findings for constructing claims and proposals, 4) Discussing and arguing on the strengths and weaknesses of their claims (accepting or withdrawing claims) and 5) Organising their claim presentation and reflecting. In terms of students’ enhancement for collaborative work, both the adopted inquiry-based process and the argumentation-debate nature of the project triggered students’ willingness to work collaboratively in small groups and undertake subtasks that would finally inform an inclusive and explicit scientific inquiry. In a teacher’s working group progress report it is stated "… *students collaborated creatively overcoming their disputes, managed to put aside their competing for grades and became friends with classmates who did not know well…*". In addition, all the working groups, after they had completed their scientific inquiry they wanted to communicate their findings not only to their school unit, but also to the wider community in which their school was located in order to appeal for collective action.

3.4. Elements Addressed in the Research Tool

A process evaluation questionnaire (see Appendix) was used for this research with a main focus on evaluating students' beliefs about the argumentation/debate approach and its collaborative nature as an educational practice addressing STEM courses. In addition, the questionnaire aimed to identify and evaluate the impact factor of this implemented approach on students' attitude towards STEM sciences. The questionnaire was designed and structured around four sections: (i) preparation, (ii) evaluation of the event, (iii) impact of the event, (iv) suggestions for improvement and other commentary and (v) participants personal data. The first three sections were structured around specific categories and relevant subsequent indicators (Table 1). By addressing these issues our main objective was to define the effectiveness of the argumentation/debate approach in students' attitude towards STEM courses.

The questionnaire consisted of 8 items comprised of Likert-type questions. Students had the opportunity to tick one answer in each question, or to not give an answer at all. Only the section "IV – Suggestions for improvement and other commentary" was an open question. From a total number of 130 students, 74 handed back the questionnaire which equates to a return rate of 56.92 %.

Table 1. Topics, categories and indicators addressed by the research tool

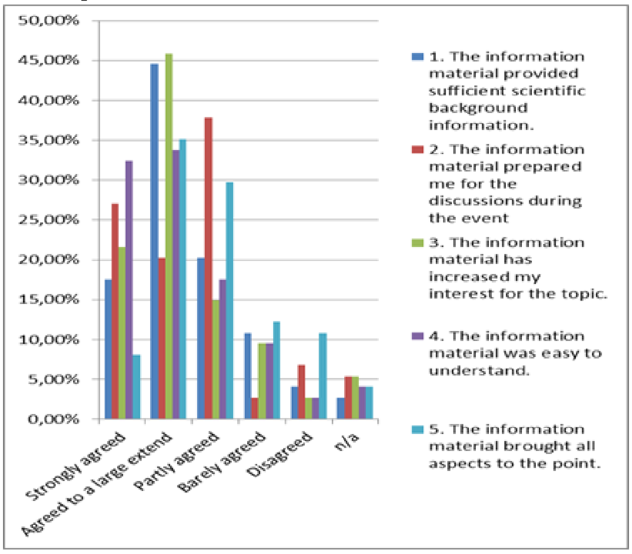
Topics addressed	Categories	Indicators
Prep Preparation	Assessment of the information material prior to the event	providing sufficient scientific background information, sufficient preparation material, interesting, comprehensible, bringing all aspects to the point
Eval Evaluation of the event	Evaluation of the working group sessions	Useful, interesting, facilitating participants' contribution, raising questions that participants will continue to deal with
	Evaluation of the parliamentary debates	interesting, facilitating participants' contribution, raising questions that participants will continue to deal with
	Evaluation of the collaboration with the scientists	students' beliefs on: scientists' comprehensible elaboration of scientific concepts, successful delivering of useful insight into their research and students' interaction with scientists as a successful way in eliciting students' interest in the topics under negotiation
	Rating the importance of parts of the event	The content of the preparation, introductory lecture, discussions in the working groups, parliamentary debates, dialogues with the scientists, cooperation with the moderators
	Degree of satisfaction with the event	pleasant working atmosphere, comprehensible tasks, facilitating contributions, useful participant contributions, satisfaction with the course of the event
ImImpact of the event	Lessons drawn from event	Acquiring knowledge on the topics under negotiation, engaging students in further topic research, motivating for eliciting students' participation in future ESP, becoming aware of parliamentary decision-making processes, motivating for students to follow scientific careers, positive attitude towards scientists

3.5. Questionnaire Analysis and Results

In the first section 'Preparation', students were required to assess the information material that they had received prior to the event. The section included two questions. In the first question in which students were asked about the source of acquiring information for the Student Parliament they all indicated their teacher (100%). The second question (Figure 2).

'How do you assess the information material that you received prior to the event?" was comprised of statements that students had to evaluate on a five-Likert scale from 'strongly agree' to 'strongly disagree'. According to the gathered data, it was found that the content and significance of the material that the students had received prior to the event was evaluated positively and the students agreed that it was an important part of the event (Ø 1.75; 78.3 % (very) important). A great part of the participants (62.2 %) agreed that the material provided necessary information and that this was very helpful for the scientific discussions (47.3 %) and increased their interest for the topic (67.5 %). In addition, many students (66.2 %) agreed that the material was easy to understand and that it brought all aspects to the point (43.2 %). More than half of the participants (54.0 %) agreed that the introductory lecture was also an important part of the event (Ø 2.59).

Table 2. 'How do you assess the information material that you received prior to the event?'



In the second section addressing the issue of evaluation of the event there were 5 Likert type questions. The first question involved (Table 3): the evaluation of the working group sessions in terms of usefulness for exploring the topics under negotiation, interest, participants' facilitation for contributions and indicating interest in further exploring the questions raised during the group work. The second question referred to the evaluation of the actual parliamentary debates (Table 4) and in particular it explored whether the students had considered the approach as interesting and had managed to contribute successfully their opinions and if the students believed that the debates had raised questions that they would continue to deal with. The third question (Table 4) 'How do you evaluate the collaboration with the scientists?' concerned students' beliefs on scientists' comprehensible elaboration of scientific concepts and successful delivering of useful insight into their research and students' interaction with scientists as a successful way in eliciting students' interest in the topics under negotiation. In the fourth question, students were required to evaluate in terms of importance several parts of the event: the content of the preparation, the introductory lecture, the discussions in the working groups, the parliamentary debates, the dialogues with the scientists and the cooperation with the moderators. Finally, in the fifth question students were required to express their satisfaction regarding the event considering the working atmosphere, the degree of comprehensibility of the assigned tasks, the provided possibilities for contributing their ideas and the usefulness of the other participants' contributions and the degree of satisfaction of the course of the event. In general, the evaluation of the event in Athens was evaluated positively by the students. Particularly, the working group sessions were evaluated to be an important part of the event (Ø 1.96; 72.9 % (very) important). To a great part of the students (79.7 %), these sessions were very useful to investigate the scientific topic of the parliament. In addition, many participants also found the group work very interesting (78.3 %) and contributed their opinions during the sessions well (67.6 %). Almost half of the participants (47.3 %) will continue dealing with the questions that were raised during the group work. The cooperation with the moderators was seen as an important part of the event (Ø 2.07; 67.5 % (very) important) as well. In addition, to the majority of the students (Ø 2.26; 56.7 % (very) important), the parliamentary debates were a very important part of the event, as a great part of the participants (63.5 %) assessed the debates as interesting. More than half of the participants felt that the contribution of their opinions was easy during the debates (55.4 %). Many students (44.6 %) indicated that they will continue to deal with the questions that were raised in the debates. Furthermore, the dialogues with the scientists were seen as an important part of the event (Ø 2.35; 60.8 % (very) important). The majority of the students (81.1 %) thought that the scientists expressed themselves comprehensibly and that they delivered useful insight into their research (56.1 %). For most of the students (52.7 %), the interest in the topic was increased through the dialogue with the scientists.

All in all, the participants were very satisfied with the Student Parliament in Athens as a whole (Ø 2.14; 68.9 %). The working atmosphere during the event was very pleasant to most participants (56.7 %). Most students also agreed that the posed questions were comprehensible and therefore good to work on (75.6 %). A good part of the participants (67.5 %) also thought that they contributed their own opinion well and that the contributions by other participants were helpful (52.7 %).

Table 3. Evaluation of the working group sessions

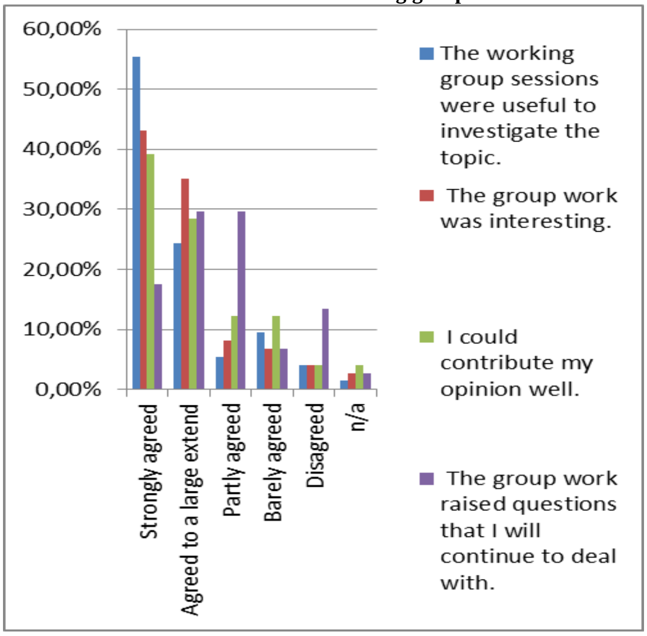
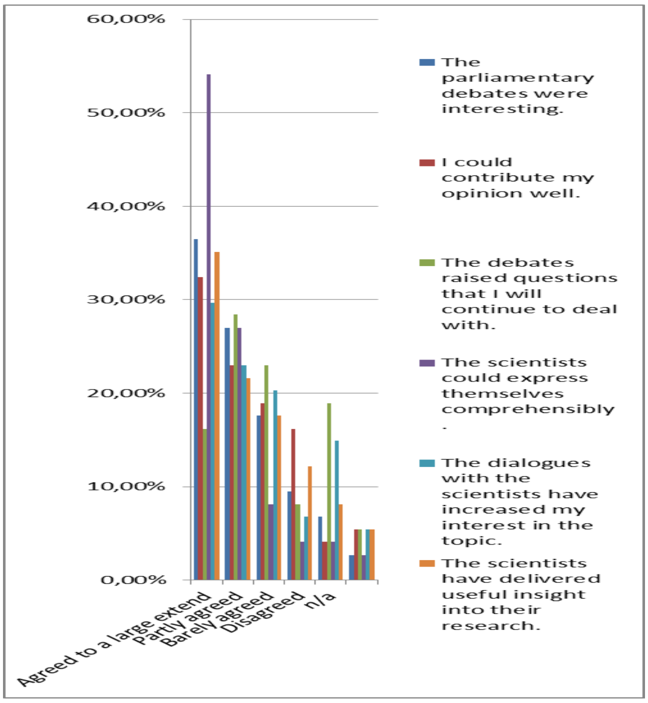
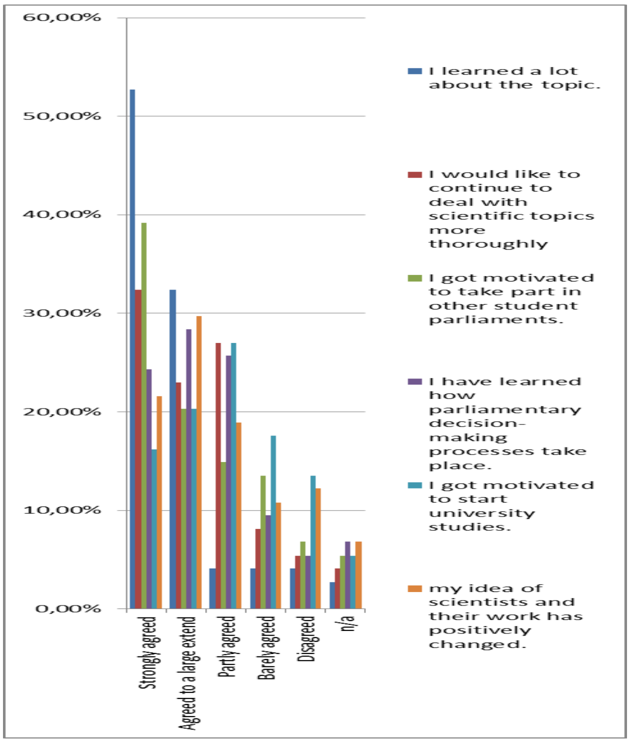


Table 4. Evaluation of the parliamentary debates and collaboration with scientists



In the third section addressing the issue of the impact of the event students were required to express their degree of agreement regarding six statements: (1) I learned a lot about the topic, (2) I would like to continue to deal with scientific topics more thoroughly, (3) I got motivated to take part in other student parliaments, (4) I have learned how parliamentary decision-making processes take place, (5) I got motivated to start university studies and (6) my idea of scientists and their work has positively changed (Table 5). As regards the impact of the Student Parliament in Athens, the participants confirmed various effects and lessons drawn from participating in the event. Many participants (85.1 %) agreed that they had learned a lot about both the scientific topic “The future of our city” as well as about parliamentary decision-making processes (52.7 %).

Table 5. Evaluation Evaluation of the effect of the event



More than half of the students (55.4 %) indicated that they would continue to deal with the topic and some participants indicated that they got motivated to start university studies (36.5 %). For a good part of the students (51.3 %) the idea of the scientists and their work had positively changed through participating in the Student Parliament. Finally, many participants (59.5 %) got motivated to take part in another student parliament.

The fourth section included an open question where students could write their comments and indicate suggestions for improvement of the learning process and the event. Their suggestions mainly addressed positive comments on the process (65%), the issue of inability for all students’ transportation to Copenhagen (26%), and the need of more support on the part of scientific experts (9%). In terms of students’ personal information, regarding age and gender, that was gathered in the fifth section, it was estimated that the participants were between 12 and 18 years old with an average age of around 15 years. In addition, 66 % of the students were female and 22 % male.

4. Conclusions and Discussion

In this paper we attempted through the case study of EUSP in Athens to show how argumentation is situated in science education and its beneficial contribution in advancing students’ understandings of the epistemology of science. In order to initiate students into the principles of authentic scientific practice students should be engaged in meaningful and challenging activities and learning processes that are guided by the epistemology of science [33]. In addition, collaborative learning in the form of argumentative discourse in the context of problem-solving situations is an empowering interactive learning mechanism that enhances students’ constructive thinking and development of analytical and critical skills [15,35].

Our research findings have indicated the participants’ positive stance (63.5 %) towards the argumentation/debate approach as an educational practice addressing STEM courses and its contribution to their acquisition of scientific knowledge (85.1 %). Moreover, students seem to support the collaborative approach as a facilitating mechanism for construction and advancement of knowledge (72.9 %) and they have identified the significance of scientific experts’ contribution and scaffolding (60.8 %) in their learning process. Indicative of their positive stance towards the argumentative learning practice is the positive impact factor of this implemented approach on students’ attitude towards STEM sciences (51.3 %) and their expression of willingness to further explore the scientific issues under negotiation (55.4 %). According to the analysis of the applied research tool, the students evaluated the Student Parliament in Athens very positively. The event was seen as enriching for further engagement with the scientific topics as well as political processes and structures. The majority of the participants were satisfied with the preparation and implementation of the event. Especially the working group sessions and the cooperation with the moderators were seen as useful and important. Students indicated as crucial parameters for their task engagement the interactive and interdisciplinary format of the parts of the EUSP events. They specifically attributed their active engagement to the authentic context and content of the learning task, the relevance of the issues under negotiation to their lives and the fact they had the possibility to contribute their opinion (67.5 %).

The analysis of the learning environment and process adopted in the EUSP context gave us an insight into the learning benefit of having the argumentation approach embedded in the learning task and not disconnected from learning science. The learning environment of the EUSP organized around authentic activities and issues relevant for students’ lives facilitated students in inherently adopting the scientific inquiry approach in order to strengthen their performance in the debate process. Students were inherently prompted to analyze their opinions, find evidence to back their claims and consequently generate and construct solid and advanced knowledge. In addition, scientific experts and teachers’ scaffolding support contributed to students’ guidance and progressive adoption of the inquiry model as well as eliciting the metacognition process that requires students’ explicit references to their thinking and cognitive processes. In the case of metacognition students are both required to reflect on their arguments-learning as an inherent feature of the argumentation process but also to become aware of the applied cognitive strategies and conceptual changes and metaconceptions [24,25]. A key feature in the enhancement of the metacognitive approach in the context of the argumentation was students’ engagement in the negotiation of the problem-solving issues in collectives. The construction of arguments in this case is realized with the contribution of inputs from various participants engaged in an interactive discourse [15] while sharing the same goal and mutual prospects of developing irrefutable and solid evidence-based arguments that will strengthen their case during the debate. Students' engagement in a joint attempt of mutual understanding through argumentation interactions [41] facilitates and enhances an in-depth knowledge co-construction [15,16]. In addition, the efficiency of the argumentation approach, as realized in the EUSP context is also documented by the impact factor of the specific learning process on students' attitude towards STEM sciences and their expression of willingness to participate in further events and similar learning tasks.

Given the beneficial educational outcome of the argumentation approach regarding students' cognitive development and construction of solid evidence-based knowledge it is necessary to guide science teachers through its proficient implementation in their teaching practices. Although lessons that are based on argumentation and critical thinking cannot be developed in the form of structured instructional scripts [6,39], they necessitate teachers' adoption of student-centered pedagogical theories, focus on high order cognitive skills and teachers' use of argumentation discourse and subsequent strategies [45] as a core feature in their teaching of science. Since teachers' use of language influences the pedagogy of science [39] maybe the adoption of argumentation discourse in science courses will manage to bring a significant change in the overall pedagogical context that surrounds science teaching.

Acknowledgement

The "European Student Parliaments" (EUSP) project (http://www.student-parliaments.eu/), its main organizer "Wissenschaft im Dialog" and the Science View Organization (http://www.scienceview.gr/) responsible for the organization of the European Student Parliament in Athens, Greece.

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