American Journal of Educational Research, 2020, Vol. 8, No. 1, 16-23
Available online at http://pubs.sciepub.com/education/8/1/3
Published by Science and Education Publishing
DOI:10.12691/education-8-1-3

Investigating the Impact of the Duration of Engagement in Socioscientific Issues in Developing Greek Students' Argumentation and Informal Reasoning Skills

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Received November 15, 2019; Revised December 21, 2019; Accepted January 07, 2020

Abstract Argumentation seems to play a central role in science education. Among other factors that could affect students' argumentation skills, the duration of their engagement in appropriate teaching environments or teaching interventions have been studied, yielding opposing results. Thus, the aim of this research was to shed light in this direction. For this purpose, we worked with 10th grade Greek state school students divided into two groups. Both groups attended a course called "Research Project" (RP), which aimed to approach the teaching of Biotechnology through socioscientific issues. The first group attended the course for two hours weekly for twenty weeks (long research project group – LRP), whereas the second attended the same course with exactly the same designing for three hours per week for 13 weeks (short research project group – SRP). At the end of the interventions, all students completed a questionnaire of eight open-ended questions on Biotechnology. Students were asked to express their opinion providing arguments which later were assessed using Toulmin's model. Simultaneously, we estimated the informal reasoning they used to express their arguments, based on the classification: rationalistic, intuitive and emotive. The results revealed that students of the LRP group produced stronger arguments using rationalistic informal reasoning that is arguments of higher level supported by scientific data and multifaceted consideration of each issue of question, compared to the SRP group. Moreover, the intuitive informal reasoning was found to be significantly reduced statistically in the LRP group compared to the SRP group. Consequently, we concluded that the distribution of RP teaching periods throughout the school year was crucial to enhancing both students' argumentation skills and their informal reasoning when expressing arguments. In other words, an intervention of longer duration can help students formulate more elaborate arguments based on scientific data.

Keywords: *argumentation, informal reasoning, socioscientific issues, Biotechnology, duration of intervention, Research Project*

Cite This Article: Martha Georgiou, Evangelia Mavrikaki, Krystallia Halkia, and Issidora Papassideri, "Investigating the Impact of the Duration of Engagement in Socioscientific Issues in Developing Greek Students' Argumentation and Informal Reasoning Skills." *American Journal of Educational Research*, vol. 8, no. 1 (2020): 16-23. doi: 10.12691/education-8-1-3.

1. Introduction

Much research has recently been conducted regarding argumentation that has either focused on the estimation of students' ability to produce arguments [1,2,3,4] or on the didactic context which could promote argumentation skills [1,5,6]. Some researchers suggest didactic methods to enhance the ability of developing arguments [7], whereas others investigate the role of teachers on students' argumentation skills [8,9]. It is obvious that argumentation has various dimensions and it is at the centre of research in the field of Science Education as it is a critical element of scientific practice [10,11].

But how is argumentation defined? According to Patronis, Potari and Spiliotopoulou (747-748) [12] argumentation is a "social process, where co-operating individuals try to adjust their intentions and interpretations by verbally presenting a rationale of their actions". Furthermore, the term also refers to the process of the negotiation and formulation of an argument [13], either collectively or individually, which can be expressed in written or spoken language [14]. In this process, an argument, which can arise following an individual's or group's activity [15,2], is the tool that promotes argumentation as it connects claims and justification using supporting data [1,16,17] when defending various issues.

2. Theoretical Framework

2.1. SSI Context in Expressing Arguments Based on Informal Reasoning

Socioscientific issues (SSIs) are considered the ideal context for the development of argumentation [1,18]. SSIs are those issues that exhibit a scientific aspect which at the same time have social implications that do not have a unique solution [19]. For instance, genetically modified food, mobile phone use and the creation of transgenic animals and plants are everyday issues that require decisions and solutions supported by documented views.

It has been reported by Sadler and Zeidler [20] that the negotiation and resolution of complex issues is directed by informal reasoning. Informal reasoning includes the cognitive and emotional processes that contribute to solving such complex issues as SSIs. Moreover, it is has been shown that people employ informal reasoning in order to elaborate on controversial issues which have multiple solutions, a description which clearly corresponds to SSIs [21,22,23]. According to the latter, informal reasoning plays an important role when problems are open-ended, complex and controversial, thus requiring individuals to construct arguments to support their claims about these issues.

Therefore, the link between informal reasoning and SSIs is evident. If we also consider that the argument is the expression of informal reasoning [24], the inseparable connection between the three becomes clear.

2.2. Achievement of Argumentation Skills in Science Education

The role of argumentation is central in both education and science. Teaching methods that strengthen argumentation are considered to be at the heart of effective teaching [25]. It is also argued that argumentation should be incorporated into the teaching of science as it constitutes an integral part of the practice of science [17]. However, although efforts towards the promotion of argumentation in the classroom do exist, as is evidenced by the inclusion of argumentation in the curricula of many countries [17], research has shown that students face particular difficulties in developing arguments [26]. Specifically, when students are engaged in argumentation procedures aiming at the building of arguments, they are not able to successfully articulate persuasive arguments [27]. It has been suggested that such difficulties may arise as a result of the lack of opportunities for students to participate in argumentation procedures [15], especially since these skills can be cultivated either by explicit argument manufacturing instruction [1] or by creating the conditions under which students will have ample opportunities to engage in dialogues that require arguments, through appropriate activities and operations [5].

At the same time, some researchers support the view that developing argumentation skills is a long-term process [13], while others have proven that it could be a short one [1]. For example, working with first year college undergraduates, Zoller [28] found that higher-order cognitive thinking cannot be achieved in only one semester; more time is needed. Osborne et al. [13] supported this conclusion with similar findings from their research in United Kingdom: After nine argument-based lessons, approximately one per month over the course of one year, 8th grade students (aged 12-13 years) improved their argumentation skills when expressing their viewpoint about a SSI related to zoos. On the other hand, according to Venville and Dawson improvements in the structure and complexity of students' arguments, the degree of their rational informal reasoning, and their conceptual understanding of science can occur after only a short intervention of three lessons. Hefter at al. [29] concluded that their short-term training intervention successfully fostered development of three components of argumentation skills (i.e., evaluative knowledge, generative knowledge, and argument quality) as well as increasing students' declarative knowledge about argumentation. Nevertheless, the stability of all these components was not achieved except in the case of the declarative knowledge. In other words, it is obvious that the issue of an appropriate period of time that could ensure the improvement of students' argumentation skills should be clarified. Our research aims to contribute to this end by shedding more light on the issue through the comparison of the results achieved by implementing the same teaching intervention for two different periods of time, using the teaching opportunities available within the Greek educational system.

2.3. Argumentation through the Greek Educational System

In the Greek educational system, there are few opportunities for students to develop arguments – and thus express informal reasoning – in SSIs, as neither explicit argumentation instruction occurs in science classroom, nor are the appropriate conditions for engagement in argumentation activities ensured. However, in the school year 2011-2012, a new course called "Research Project" (RP) emerged in the curriculum of the 10th grade. This course is designed so that groups of 16-20 students work on a topic they choose from among different topics suggested by teachers. Students carry out research on the topic under their teacher's supervision. In light of the conditions mentioned above and given that Greek students face difficulties in the construction of arguments (authors 2013), we considered that the RP could be an appropriate framework for the promotion of argumentation and informal reasoning to students, especially through the integration of SSIs, as these provide an ideal context for informal reasoning and argumentation. In particular, we used the field of Biotechnology to investigate whether students' argumentation skills could be improved, and also to examine the type of their informal reasoning, when engaged in SSIs during RPs of two different periods of duration. Therefore, the research question that arose was:

How does engagement in RPs with two different periods of duration affect argumentation skills and informal reasoning of 10th grade Greek students when expressing their views on SSIs related to Biotechnology?

3. Methodology

3.1. Research Sample

The research sample consisted of 36 students divided in two groups: the SRP group (*Short Research Project*, n=16) and the LRP group (*Long Research Project*, n=20). They all attended the same school in Athens and they all were mean achievers according to their teachers. Between the groups there was an equal distribution of gender and, most importantly for our research they had never been taught argumentation skills.

3.2. Approaching Biotechnology through the Research Project

The field of Biotechnology includes a wide variety of modern SSIs, such as genetically-modified organisms, cloning, gene therapy etc., making it suitable for our research. Students of both the SRP and LRP groups chose a topic from this field which had been proposed by the teacher to work on. The SRP group attended the RP course for three hours weekly during 13 weeks (39 hours in total), whereas the LRP group had attended the RP course for two hours per week for 20 weeks (40 hours in total). Consequently, it is obvious that even if the total amount of hours that students of both groups had attended the RP course is the same, the duration of the procedure differed.

During the RP, students had precise missions to fulfill. Table 1 shows the precise program of the RP, through which students attempted to provide solutions to the following issues:

- You are a scientist in a laboratory of Molecular Biology of an agronomic company that sells plant seeds to professional farmers. You are asked by your employer to construct genetically-modified rice seeds. Are you willing to comply with the institution's mandate? Please justify.
- In recent years the intervention in human genetic material for therapeutic reasons is a fact. However, it is said that a few years from now the intervention in the genetic material could be extended to the point where genes responsible for intelligence could be added to DNA of embryos at the request of their parents. What is your opinion on this issue? Should those techniques that have been introduced for therapeutic reasons also be used to enhance human intelligence too? Please justify.

Hence, students were engaged into these two different SSIs which they had to investigate and express their views on. After prior questioning and briefly discussing these SSIs, students sought information (on the Internet and in the press as well) that could help them unpack the SSI and formulate proposals.

By working in groups of four, which were randomly created, students managed to collaboratively gain an understanding of some essential concepts of Biotechnology. After completing their investigation and reaching a decision concerning the SSI they were engaged in, each group presented their results to the entire class in a plenary session.

Thus, all the groups had reached a decision concerning the SSI they were engaged in, and they presented their decision to the entire class. It should be noted that the role of the teacher throughout the conduct of the RP was supportive and encouraging. In some instances, explanations and clarifications were provided after students' requests if this was considered necessary. In general, the teacher held the role of facilitator.

3.3. The Research Instrument

To collect the research data, we created a questionnaire consisting of eight open-ended questions about various SSIs from the field of Biotechnology. They were structured around specific axes derived from the 2010 Eurobarometer [30], an EU-wide survey conducted by the European Union approximately every 4 years mainly to highlight the attitudes of European citizens on issues about Biotechnology. The axes that the questionnaire was based on were Health, Environment, Food and the effect of Biotechnology on them. Hence students were asked to answer questions as:

Your parents entrust you to buy vegetables that are necessary for your family for a week. You need potatoes, tomatoes, eggplants and lettuce. At the market, you see that there are several options for all four types of vegetables. Specifically, there are three crates of potatoes: one with the inscription "biological", one with the inscription "genetically modified" and one with the inscription "conventional crop" (i.e. produced in a traditional way). Which one would you prefer if all of them cost the same, and why? Or

In your area the Mayor approved the operation of a factory that produces genetically modified microorganisms that help in the cleaning of oil spills. Some of the residents are up in arms against the operation while others support it. What is your opinion and why?

A general question about Biotechnology that did not fit into any of the above categories was also included in the questionnaire so that students could develop their arguments by drawing elements or presenting data from any of the above categories.

3.4. Data Collection

At the end of the school year the questionnaire was distributed to all students, who were asked to complete it anonymously. It was emphasized, both in writing - properly indicated on the questionnaire - and orally- at the beginning of the process- that they could freely express their opinions supported by relevant arguments on every question. In the end, we collected 288 answers.

3.5. Data Analysis

3.5.1. Argumentation

To assess the level of students' arguments we used the Toulmin model [16] (Toulmin's Argumentation Pattern-TAP), which is based on the structure of an argument in order to evaluate its 'robustness'. We chose this model since our focus was on the structural elements of students' arguments, which fits better with our interest in argumentation in general, and also because TAP has been used in the majority of similar studies [3,31,13,32].

Furthermore, the use of TAP was appropriate as our next step was to make comparisons between the sample of this research and samples of similar studies [6,33]. Based on TAP, the six components of a complete argument are the following: claim, data, warrant, backing, qualifier, rebuttal.

According to Toulmin [16], the *claim* is the position of the individual asked, based on specific *data*. The way that data are associated with the claim, in other words the path followed from the data to the claim, is the *warrant*. Of course, the warrant may be supported by further data, the *backing*, that have the effect of further strengthening the warrant. On the other hand, the *qualifier* testifies the confidence level of the claim and finally, the conditions under which this claim is not valid are covered by *rebuttals*.

The TAP was used in combination with the scale of [3], which is essentially a modification of the scale proposed by [2]. This final scale includes four levels. The first level includes arguments that simply consist of a claim. In the second level we find arguments that, in addition to the claim, also include some data and/or warrants, explaining how the data are connected to the claim. Arguments that contain claim, data, warrant and backing or qualifier are ranked as third level, while at the fourth level we find arguments with claim, data, warrant and backing and qualifier.

Nevertheless, we had to slightly modify a bit the scale by adding a fifth level, since in the students' written responses we collected, we detected some rebuttals, which are usually difficult to locate in written arguments. The rebuttals are primarily dialogue products in the sense that the respondent rejects an argument that another discussant raised in order to highlight the validity of his or her claim. Sometimes, the respondent may attempt to degrade the argument raised in advance, indicating the circumstances/ reasons which make it invalid. This is exactly what can happen in a written argument. For these reasons, we modified the scale of [3] by adding a fifth level, which would contain all the components of the fourth level did, plus at least one rebuttal. Table 2 summarizes the levels of this 5-level scale.

3.5.2. Informal Reasoning

In order to detect the kind of students' informal reasoning we used the model of [20]. This model considers three types of informal reasoning. The types that make up the model are *rationalistic*, *intuitive* and *emotive* (Table 3). According to those authors, the rationalistic type refers to logical reasoning, based on scientific understanding and weighing the risks and benefits, disadvantages and advantages of an issue. The intuitive type refers to considerations that arise through an internal feeling and a quick response. It reflects personal entrenched beliefs often governed by negativity and usually precede rationalistic and emotive type. Finally, the emotive type refers to considerations that arise from emotional reactions to stakeholders, from caring about, or having empathy, sympathy, compassion or concern for the suffering of those affected.

As the students' responses could be based on more than one kind of informal reasoning, we created categories of all different combinations that we could possibly detect. Consequently the categories that emerged were: R (rational), I (intuitive), E (emotive), IR (intuitive and rational), ER (emotive and rational), IE (intuitive and emotive) and IRE (intuive, rational and emotive).

Table 1. The activities of the RP per teaching hour

Teaching hours	Activities
2	Acquaintance – groups' formation–transcription of session's work on to paper[1]
2	Contract[2]- techniques to be used (painting - search and assessment of Internet resources- keeping team's portfolio- keeping diary- communication by email/ logging in/ instructions)
2	Completion of second week's activities
2	Educational visit[3]
2	Presentation of the RP's subject[4]- discussion about the issue. Internet research (all groups)
2	Presentation of results in plenary session- assessment/ defining each group's areas of work on Biotechnology (health, agriculture, raising livestock, environment, industry)
3	Internet research of each group on its area of work
2	Internet research of each group on its area of work
2	Visit to the Municipality library - research in published materials
3	Development of each group's views (about the SSI asked) in writing
2	Development of each group's views (about the SSI asked) in writing
2	Plenary presentation by three[5] groups
1	Plenary presentation by two groups
2	Transcription of two last sessions' work on to paper[1]
2	Completion of research questionnaire by students
2	Discussion about RP- students impressions
2	Presentation – Power point construction
2	Power point construction
2	Presentation rehearsal
1	Presentation[6]

Notes:
[1] A3 illustrated posters.
[2] Selection and imprinting of the rules which apply in the classroom during the RP.
[3] Visit to the University of Peloponnese and workshop attendance on the selection and assessment of Internet sources.
[4] The teacher introduces SSIs and discusses with students.
[5] two groups in the case of SRP (in one teaching hour).
[6] Presentation of the RP in front of all 10th grade's students.

Table 2. Examples of students' responses regarding the level of the argument

Argument level	Description	Example
1	Claim	[I suggest] Not to buy the field (claim).
2	Claim, data and/or warrant	I would prefer biological potatoes (claim) because they have been cultivated in a manner that isn't harmful to the environment (data) as I don't want either to pollute it, either (warrant).
3	Claim, data, warrant, backing or qualifier	I agree with the method of gene therapy (claim) because too many malfunctions, that may occur in an organism, could have been avoided through this method (warrant) with the integration of appropriate proteins (data). For example, if a child's parents are prone to some kind of disease, gene therapy manages to eliminate this weakness that may occur in the child's body (warrant). Also this method can bring positive results even to people who already suffer from a disease (backing).
4	Claim, data, warrant, backing, qualifier	Oil spills are especially harmful for marine life (warrant) because many fish are killed and some of them are endangered species (data). The oil spills have to be tackled and these microorganisms are definitely the solution (backings).Therefore, I support the operation of the industry (claim) only if it doesn't pollute the environment (qualifier).
5	Claim, data, warrant, backing, qualifier, rebuttal	No I don't agree (claim) in any case (qualifier).Various disease treatments could be developed in this way, but it is doubtful because there is a possibility that animals died by the introduction of new genes (rebuttals). I would like to become an environmentalist (data) so I have to be constantly aware of the environment and the organisms (warrant). Moreover, this process would be against my principles (backing).

The assessment of the arguments' level and the kind of informal reasoning students used to express them was performed individually by each researcher. The initial rate of agreement for the argument level was 94% and for the informal reasoning 96%, which after an extensive discussion was raised to 98% for both criteria, thus ensuring the reliability of the results. The comparisons between groups were realized via independent sample *t-test*, using the statistical package IBM© SPSS 22.

4. Results

The analysis of levels of students' arguments led to the distribution presented in Figure 1.

The arguments developed by the LRP group were much more elaborate than the arguments of the SRP group, and these differences are statistically significant *[$F_{(=}$0,045, t=3,908, p=0,00<0,05]*. Thus, it became obvious that students who had attended the RP for a longer period of time produced arguments of higher levels than students who had attended the RP for a shorter period. More specifically third-level arguments were mostly formulated from the LRP group of students (20,75% by the LRP students, and 10,74% by the SRP students), while fourth- and fifth-level arguments were produced exclusively by the LRP group. Lower level arguments were mostly expressed by students in the SRP group (i.e. 95,05% in total for the first and the second levels).

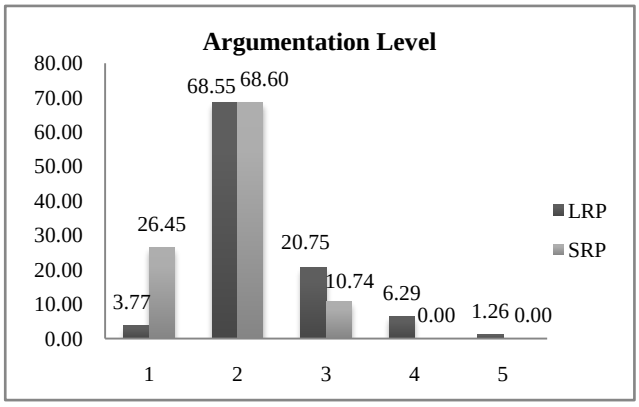

Figure 1. Distribution (%) of students' responses per argument level and group

The findings that arose regarding students' informal reasoning are presented in Figure 2. In order to compare the different types of informal reasoning between groups, we first added all the answers of the same type. More specifically, all responses containing R type were summed (i.e., R+IR+ER+IRE=total R) and the same calculation occurred for I and E types. After that, statistical analysis was performed. Thus, we identified that rational reasoning was used more often by students in the LRP group than by those of the SRP group *[F=0.06, t=4.475, p=0,00<0,05]*. 62.89% of the LRP participants' responses were based on scientific data (rational informal reasoning), while only 24.81% of the SRP responses emerged through logical reasoning. Nevertheless, a statistically significant difference emerged not only in the case of the use of rational informal reasoning, but also in the use of the intuitive one. In fact, the LRP group was found to draw on intuitive informal reasoning less than the SRP group *[F=0.003, t=-2.342, p=0.025<0.05]*. Speaking in terms of descriptive statistics, we found 74,39% of intuitive based arguments for the SRP group, while this percentage was limited to 45,51% for the LRP participants. According to the analysis of our results, emotive informal reasoning seemed not to have been affected,, as we did not capture statistically significant differences between the groups *[F=3.06, t=-1.006, p=0.321>0.05]*. Moreover, none of the students of both groups gave "I don't know/ I won't answer" responses.

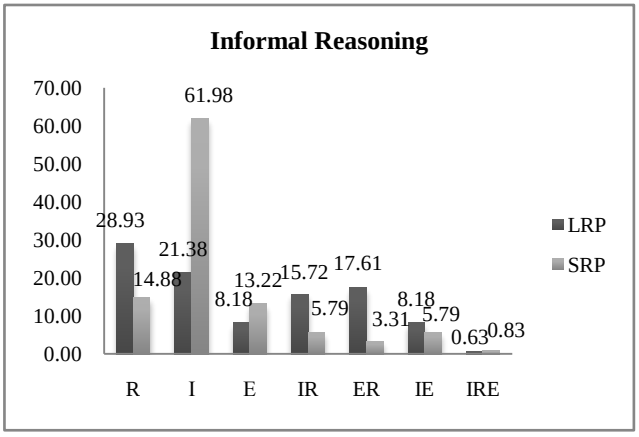

Figure 2. Distribution (%) of students' responses per type of informal reasoning and group

Table 3. Examples of students' responses regarding the type of informal reasoning

Type of informal reasoning	Description	Example
Rationalistic	Logical reasoning, using scientific knowledge and weighing the risks and benefits, disadvantages and advantages.	"I would prefer the biological ones [potatoes] because I would not be aware about the type of the gene added in the genetically modified potatoes."
Intuitive	Reasoning arising by an internal feeling and a quick response. It reflects personal rooted convictions, instinctive reactions and it is often governed by negativity.	"I would prefer either the biological [potatoes] or the ones from a conventional cultivation, because the genetically modified potatoes will not be good for us."
Emotive	Reasoning resulting from emotional reactions to stakeholders, i.e. from caring about, or having empathy, sympathy, compassion or concern for the suffering of those affected.	"No I would not agree [to sell a goat herd in order to create transgenic animals for the production of pharmaceutical proteins] because animals are continuously exploited by people for their own benefit and no one respects them."

5. Discussion

In this research, we examined both the argumentation level and the type of informal reasoning that 10th grade Greek state school students used when asked about SSIs from the field of Biotechnology after having been engaged in an RP for two different time periods in this field.

Our findings indicated that engagement for a longer period can enhance students' argumentation skills not only at the level of structure, but also at the level of the type of informal reasoning they rely on when arguing.

Participation in the RP for fewer hours per week over two semesters, rather than more hours per week in one semester, gave students time to become familiar with both this new way of working in class, gradually disengaging themselves from the traditional classroom approach (mostly used in Greece [34]), and the corresponding way of thinking, i.e., elaborating on their arguments. Other researchers have also found that argumentation can be improved through an extended teaching process [13,28], which is in line with our findings. Of course, as already mentioned, students' argumentation skills can be developed through presenting them with appropriate opportunities [5]. Hence, we suggest that opportunities generated through an RP with embedded SSIs could contribute to empowering students' argumentation skills as this approach facilitates their coming into contact with another view, one in which science is connected to social issues. So, an RP with embedded SSIs requires students to examine all aspects of the issues, which distinguishes an RP from the traditional approach, where the class is teacher-dominated and the scientific knowledge is presented to students as fragmented references to issues in society. In contrast, in an RP, students are called upon to collaboratively make a decision regarding a specific SSI by evaluating multiple criteria regarding both the relevant scientific knowledge and the social implications of the SSI. Needless to say, this process takes time, and for the incorporation of SSIs into existing school courses to be effective, sufficient time for completion of the activities that teachers design should be available in the curriculum. 72,32% of LRP group's responses were classified as 1st and 2nd level arguments, which means that even if those students could express their opinion providing more complete explanations based on scientific elements, the majority of the responses were limited in low argumentation levels, and consequently the argumentation skills of the students still need to be improved. A combination of both an appropriate teaching environment (as our suggestions for incorporation of SSIs in existing school courses) and the explicit teaching of arguments formulation could perhaps be the key point. Concerning informal reasoning, our findings showed that the rationalistic type was more frequently used by students of the LRP group. This means that their arguments were mainly affected by logical criteria such as scientific data. Moreover, they more frequently mentioned the advantages and disadvantages of a situation or an issue, and they took the latter into consideration when making a decision; therefore, their decision was based on the appropriate documentation. According to Sadler [19], informal reasoning in an SSI context is affected, to the same degree as is the argumentation, by the content knowledge. Thus yet again, taking into consideration that all students of the two teams had attended a course with exactly the same design and with the only difference being its total duration, the result could be interpreted as the students' familiarization with the process emerging in two semesters and not earlier. At the same time, it is encouraging to capture a statistically significant difference between the intuitive informal reasoning of the two groups. Students who had attended the longer RP managed to reduce the intuitive elements when developing their views. On the other hand, intuition dominated the responses of the SRP group. The statistically significant differences found between the groups, given that the only variable modified between them was the distribution of the teaching hours into two semesters, indicates that time, not as an absolute value but as duration, can affect the informal reasoning of students. Once again, although the teaching design was identical – i.e., all students had the same opportunities of engaging in the controversial issues of the RP in order to be informed about Biotechnology and subsequently make their appropriate decisions – the way each group arrived at their decision was different, based on their answers to the questionnaire. Moreover, taking into account that [36] view that when designing argumentation learning environments the positive impact of the lengthy teaching procedures should be considered, we feel that our findings converge with hers insofar as the limited period of time available to the SRP group seemed to be insufficient for the students to reverse their entrenched viewpoints when dealing with new knowledge and its use in possible implementations, despite their progressive engagement with the concepts and knowledge. Finally, the emotive type of informal reasoning was not found to be statistically different between the groups, which might be attributable to the different personality traits of each participant, traits which have been established for many years and may not have been affected within the time

frame chosen for this research. Besides, argumentation has a complex correlation to morality [18] which is not only a matter of period of time of engaging in SSIs embedded in RP.

6. Conclusion

Although argumentation is a central issue in numerous studies, it still has not become clear how teachers can help students to develop their skills. The proposal of this research is the utilization of an RP with incorporated SSIs, as occurs in other curricula [37], for at least a full school year. In fact, we have found that when students were involved in SSIs from the field of Biotechnology through the RP for two semesters, they managed to provide higher level arguments and to better support their views, compared to students involved for only one semester. Indeed, the former group mainly used rationalistic informal reasoning, which demonstrates that students made use of scientific data and considered every perspective of the issue in question, while the intuitive reasoning elements were found to have been significantly reduced. Despite these findings, the empowerment of student's argumentation skills is still a question of research as the percentage of low level argumentation is dominant.

The limited size of the sample could be increased in future studies, so as to provide a more complete picture. Of course, the results of our research do not promise a solution for every question regarding argumentation and informal reasoning of students, especially given its aforementioned limitation. However, they depict proposals that could be used to promote, at least to some extent, students' skills in argumentation and informal reasoning, and they underline the need for further investigation in such a central issue of science education.

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