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Identifying argumentative acts within the classroom amongst engineering students

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ABSTRACT: Students' arguments surrounding a scientific topic are analyzed. This analysis comes from research developed in the classroom where dialogic interaction was promoted. The purpose of this study has not only been to identify argumentative elements used by students during the sessions but principally to the process of discussion. Three different ways have been proposed for this analysis: speech acts, acts of argumentative process and acts of learning process, with the intention of establishing relationships between them.

KEYWORDS: argumentation, ASAC Protocol, engineering students, interaction, learning process, Pragma-dialectics

1. INTRODUCTION

If science is recognized as a collective construction, then, it is possible to consider the construction of scientific knowledge in the classroom as a social activity, and not only as knowledge transmission. This position also allows social activity to reach into professional practice, permitting broader and more developed interaction, which will consequently produce better ideas, thanks to the taking into account of more ideas and, above all, more positions. This paper is an attempt to bring together several elements around experience in the classroom (in this case the engineering classroom), in order to examine the development of verbal interaction in the construction of an argumentative discourse that leads the students to learn scientific knowledge.

Nowadays engineering, particularly civil engineering recognizes the environmental impact of construction work better than before, it is only fair to put forward a pedagogical practice that involves students in the verbal interactive dialogue in which they present their ideas, so that their more active intervention leads them to construct their own knowledge. Dialogue about the potential effects that construction works and engineering activities can have on humans and the environment must be permitted in the classroom. Engineers' work should be considered from a broad perspective (Toulmin, 2003). To that end it is proposed that critical thinking be stimulated even in the classroom by means of argumentative activity carried out as verbal interaction.

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2. ANALYTICAL FRAMEWORKS FOR ARGUMENTATION IN THE SCIENCE CLASSROOM

Currently, argumentation is recognized in science education as a highly important activity in the classroom (Osborne and Patterson, 2011). As well as promoting critical thinking, it also contributes to the building of a more democratic community in which the plurality of ideas is accepted. With regard to the evaluation of argumentation, it is important to evaluate both argumentative production and the interactive process through which the arguments are constructed.

It is not predictable which argumentative structure students or teacher will use, and therefore which analytical framework should be used to evaluate their arguments. Sampson and Clark (2008) propose two types of analytical frameworks for studying argumentation in science education, general and specific. General frameworks are distinguished because they are oriented towards structure analysis and the acceptability of the reasons included in the argument. Perhaps the general framework most used in science education is the renowned Toulmin model (2003), which recognizes six key elements in an argument: data or foundations, backing, justification, warrant, rebuttal and conclusion. Other general frameworks have been proposed by linguists such as Adam (1995) or van Dijk (1992). The specific frameworks result from the analyses put forward by science education researchers for experimental cases carried out in different disciplines and contexts. For this reason, some researchers focus on a content analysis of the justification of arguments (Zohar and Nemet, 2002); others put forward different epistemic levels for proposals (Kelly and Takao, 2002); others evaluate arguments according to a hypothetical-deductive model (Lawson, 2003); or they characterize them in terms of certain conceptual aspects (Sandoval, 2003; Sandoval and Millwood, 2008).

In short, it is possible to identify three fundamental aspects in order to analyze the quality of arguments in science education (Sampson and Clark, 2008): 1) the structure or complexity of the argument, that is, the components of the argument; 2) the argument content – evaluated according to its connection with science –; and 3) the nature of justification, that is to say, how the ideas within the argument are supported and validated.

The evaluation of argumentative activity has also been studied in science education. Enderle et al. (2010) have proposed an observation protocol that has been designed in accordance with three integrated aspects identified by Duschl (2008) in order to evaluate science learning: 1) the conceptual structures and cognitive processes used; 2) the epistemic frameworks used in developing and evaluating scientific knowledge; and 3) the social processes and contexts that shape the way knowledge is communicated, represented, defended and debated. These three aspects have been put forward by Duschl (2008) taking into account new perspectives in learning and science learning environments, as well as scientific studies about knowing and inquiring. This author highlights that the conditions for learning improve through the establishment of learning environments that promote productive and active learning by the student, and of instructional sequences that promote the integration of science learning through the three aspects, as well as activities to make students' thinking about these three aspects visible (Duschl, 2008).

Enderle et al. (2010) have proposed an observation protocol that has been designed in accordance with three integrated aspects identified by Duschl (2008) in order to evaluate science learning. Enderle et al.s' protocol takes into account the conversational approach, the use of alternative explanations, the reaction to inconsistencies, skepticism towards the ideas expounded, the relevance of reasoning, and the way students evaluate explanations. For the aspect related to the epistemic frameworks used in the development of the activity, the protocol includes an assessment by the students of the use of rhetorical tools, of the use of evidence and how it is examined, an evaluation of the interpretation of data or the collection method, the use of theories, laws, and models, the distinction that could be made between inferences and observations, and how scientific language is used. Matters related to the social aspect include the students' reflection on what they know and how they know it, respect for what the others say, the willingness to discuss ideas and the interaction that may occur (if comments are added, if questions are asked, etc.). The protocol comprises in total of 19 items according to the design of the Likert scale, and was validated by its authors taking into account the opinion of 18 experts and its implementation in 15 argumentative situations in the classroom.

Van Eemeren's Pragma-dialectical theory, presents argument as a type of interaction that arises in the context of other types of interactions, when something that has been said, suggested or transmitted shows that different parties do not have the same opinion, where argumentation arises in order to confront and try to resolve a difference of opinion through the exploration of the relative justification of the points of view presented. Pragma-dialectical theory provides a model of argumentative discourse, not so much in terms of form and content, but in terms of discussion procedures (van Eemeren et al., 2000). Van Eemeren et al. propose a scheme for an ideal model for the resolution of a critical discussion. To resolve a dispute, the points that are being questioned have to become the subject of a critical discussion whose purpose is to reach agreements on the acceptability or unacceptability of the points of view under discussion (van Eemeren and Grootendorst, 2006). In this scheme they identify four stages: confrontation stage, opening stage, argumentation stage, and closing stage. They even claim that perhaps the closest we manage to come to approaching the ideal model of a critical discussion is in scientific discussions, where at least at first, its intention is dialectical. In scientific discussions no viewpoint is accepted without having undergone a test, and the validity of the argumentation presented is rigorously examined. However, they also admit that scientists have their own unproven assumptions, their own prejudices, logical inconsistencies, etc. and that even in the more rigid scientific disciplines, occasionally passion (*pathos*) and other rhetorical resources are not always excluded. This leads to the recognition that it is premature to simply consider that scientific discussions are achievements of the ideal model. Even in this field practice often differs from theory (normative) (van Eemeren and Grootendorst, 2006).

3. EXPERIENCE IN THE ENGINEERING SCIENCE CLASSROOM

With the aim of analyzing the construction of scientific knowledge in the classroom according to the argumentative practice carried out in verbal interaction, a research project with engineering students was undertaken in the Escuela de Ingeniería de Antioquia (Antioquia School of Engineering), with the intention of bringing together theoretical foundations and research experience in order to formulate supporting elements for designing classes, the identification of methodological aspects of the exercise, and the bases for an analysis of results.

This was carried out in the classroom with groups of engineering students, from 2010. During 2010, three groups were formed on a voluntary basis with students from different semesters of the program (– between the fourth and eighth semester). These groups (of four to seven students) conducted a dozen sessions in a semester. In 2011, in addition to two other volunteer groups, the experience was taken to the regular classroom, to two fluid mechanics courses (with 22 and 26 students).

Initially (in the first year of this research project), argumentative activity began in the classroom from a historical narrative, in which the ideas under dispute were identifiable. Such ideas, which may correspond to a historical context quite distant from the present time, are still valid, especially since they involve concepts and explanations that may be in confrontation with those brought in at that time by the student. The presentation of a specific situation which may give rise to the participation of student's ideas is suitable for the promotion of argumentative activity. As it is not common for students to actively participate in the classroom, especially when the tradition of the master class has been maintained, the teacher could intervene with questions in order to explore the students' ideas. This was a situation that could be very different for each participant, and which depends on cognitive factors to a great extent, but also on aspects of the personality more connected to pathos. One of the great benefits of this activity is the discovery of student's previous ideas. This marks a course of action in the construction of the complexity of the argument that is shaped by different types of interventions. The teacher often wonders why the student does not understand or cannot resolve a particular situation. The practice of argumentation allows for an exploration of the student's previous ideas and the assessment of those ideas through the reclaiming of the elements of justification which were requested from the student, or rebuttal elements incorporated by a participant (another student or the teacher), or because a situation is introduced through which the student recognizes that the premise that he/she has submitted is invalid.

A feature which emerged as essential to this experience is the number of participants involved effectively in the activity. Participation is more difficult as the size of the group is greater. In that case, as proposed by Simon and Richardson (2009), it is recommended that the activity should be carried out in groups of a maximum of four students, and that in a later stage the interventions of the whole group should be brought together. This implies the design of didactic units for the purpose of argumentative activity. This does not mean that argumentative activity cannot be implemented in large groups; in fact it could be very interesting when, without premeditation by the teacher, students' ideas leading to the assessment of a situation, a concept or an explanation are introduced. If there is sufficient preparation to deal with argumentative activity, it is advisable to do so, as it shows that it is possible to construct knowledge from previous ideas and that science is also a space for dialogue and discussion. It is also a matter of attitude. The classroom can be a space which is completely open to argumentative activity; however, if this activity is not carried out within certain limits, it can result in a negative experience when what is actually intended is to promote the construction of arguments.

3.1. Discourse analysis in the classroom

Three categories were defined for discourse analysis in the classroom, according to the three aspects identified by Duschl (2008), which were used in the Assessment of Scientific Argumentation in the Classroom –ASAC- protocol (Enderle et al., 2010) and among which Enderle et al. have distributed the 19 items of their protocol. Each of the protocol's evaluative items was made to correspond to an identifying element for discourse analysis (Table 1). Those elements are used here as the marks of speech.

Category of Analysis	Identifying Element for Assessment of Scientific Argumentation
Conceptual-Cognitive	Statement of validation of declarative explanation Alternative statement Statement of claim of inconsistency Statement of claim of skepticism Statement of support Statement of inappropriate support Statement of validation of alternative explanation
Epistemic	Rhetorical element Statement of evidence Statement of evidence examination Statement of data evaluation Use of theories, laws and models Statement of inference identification or observation Language of science element
Social	Statement of self-reflection Statement of respect Statement of ideas opening Openness to criticism Statement of reinforcement

Table 1. Categories and Identifying Elements from the ASAC for Discourse Analysis

The key events in the learning process are also identified in the session. For this aspect, the acts listed in Table 2 have been identified for the analysis of the session to be presented here.

Finally, a discourse analysis was carried out for some episodes of the session according to the rules of Pragma-dialectics, with the identification of acts of speech and fallacies (where recognized). For the session to be presented here, the acts are listed in Table 3.

3.2. Result of the Analysis of a Classroom Session

Tools described in the previous section were used in a session (session three, of ten sessions held in the first term of 2010, with a group of five students from the second year of engineering).

Identifying Element for Assessment of Learning Process
Partial clarification
Conclusion
Confusion
Skepticism
Assessment
Inconsistent assessment
Interpretation
Opposite positions
Claim of foundations
Request for Clarification

Table 2. Learning Process Acts

Identifying Element for Critical Analysis of the Discourse
Rule 1 (of freedom)
Rule 2 (of burden of proof)
Rule 3 (of viewpoint)
Rule 4 (of relevance)
Rule 6 (of starting point)
Rule 7 (of argumentation scheme)
Rule 9 (of closing)
Rule 10 (of use)
Fallacy 10: *Argumentum ad misericordiam*
Fallacy 13: *Argumentum ad verecundiam*
Fallacy 13a: *Argumentum ad verecundiam*
Fallacy 22: *Secundum quid*
Fallacy 26: Straw man
Fallacy 34: Vagueness

Table 3. Speech Acts from the Pragma-dialectics

The study in the classroom proceeded in the following way: a brief narrative text about a fluid static situation was selected. The text had such an argumentative content that it was able to stimulate discussion among the group. The text was read out loud, so that it would be followed by everyone, interruptions were permitted (such as a request for clarification) and the reading was halted for content analysis and discussion of the ideas in the text (that is, the ideas of the reading's protagonists). From an enabling environment (of respect, trust, ideas opening) a greater interaction by participants was achieved, as shown in Figure 1 and summarized in Table 4. The total reading time was 7 min and 20.3 s with 32 interventions including repetitions. There was a large teacher participation, which can be explained by his role as motivator and advisor at the same time. The students' participations had a wide variation both in number (from 43 to 108) and time (from 2 min 9.0 s to 8 min 24.2 s). Given that some acts of participation were very short, a large number of these does not imply a greater length of participation. The longest student intervention did not exceed 1 min in duration.

In Figure 2 the identifying elements (obtained from the ASAC protocol) which have been recognized in the session are presented. There are 19 items but only ten of them were recognized in this case: four from the conceptual-cognitive aspect and four from the epistemic aspect, and two from the social aspect (Table 5). The elements of the conceptual-cognitive aspect are distributed throughout the section: the statement of claim of skepticism appears in the first 20 minutes but is more intense at the end of the session; the statement of support appears from after the middle of the session until the end; the statement of inappropriate support appears after 20 minutes of the session, and with greater intensity before the appearance of the statement of support (appropriate); and only four acts of participation are recognized as validation of declarative explanation and these appear in the middle of the session. Other defined elements are not recognized, that is to say, the alternative statement, the statement of validation of the alternative explanation and the statement of claim of inconsistency, which are the more demanding conceptual-cognitive aspects. Although the epistemic elements are also distributed throughout the session, they have a more defined pattern: the statement of data evaluation occurs at the beginning of the session; elements of scientific language appear more extensively in the middle, and more notably, rhetorical elements appear at the end; only four acts of participation are recognized as statements of identification of inference or observation. The statement of evidence, the statement of evidence examination, and the use of theories, laws and models, which are the more epistemic demanding elements, are not recognized. From the social aspect the statement of respect and openness to criticism are recognized. Statements of self-reflection, ideas opening and reinforcement are not as evident, and they are the most socially demanding.

Participant	Frequency	Times (h:mm:ss)
Reading	32	0:07:20.3
Teacher	255	0:33:59.1
Silence	38	0:02:09.0
Daniel (student)	43	0:02:39.8
Juan David (student)	108	0:04:59.1
Manuel (student)	48	0:02:20.4
Santiago (student)	82	0:08:24.2
Xiomara (student)	67	0:05:58.4

Table 4. Frequency and Times of the participants in session 3

Identifying Element	Frequency
C-C : S Claim of disbelief	17
C-C: S Support	11
C-C: S Inappropriate support	14
C-C: S Val. declar. expl.	4
Ep. : S Data eval.	8
Ep. : S Ident. inf. or obs.	2
Ep. : Science language element	8
Ep. : Rhetoric element	22
Social : S Respect	3
Social : Openness to criticism	7

Table 5. Identifying Element from ASAC in session 3

The above could lead to a rating of 26/57 according to the Likert-style scale of the ASAC protocol (Enderle et al., 2010). The interesting thing about discourse analysis using identifying elements is that it allows for the identification of how the argumentative process was carried out, which will allow for comparison with other sessions in order to assess the evolution of the argumentative process.

The learning process acts (Figure 3 and Table 6) that can be highlighted are interpretations, which occur more intensively at the beginning and in the second half of the session, requests for clarification, which are distributed almost uniformly throughout the session, and claims of foundations, which take place once the two previous acts have occurred, preceding the most intense interpretive moments. There is one expression of skepticism and seven acts of participation in which opposing positions can be found among participants, very close to the acts of conclusion. Several acts of confusion can be recognized preceding others in which part of the group expresses clarity (partial clarification). With regard to acts of evaluation, inconsistencies occur initially, but evaluations become more accurate until those inconsistencies disappear. The final conclusion results precisely from a proper evaluation.

Additionally, the session has been analyzed according to the theory of critical discussion offered by Pragma-dialectics (Figure 4). This analysis has not been carried out for the whole session but for five moments, in which there were more learning process acts and more identifying elements were recognized. Table 7 gives an account of the rules of critical discussion that are met (R1, R2, R4 and R9) and those in which fallacies are identified (R1_f, R3_f, R6_f, R7_f and R10_f), which are presented in Table 8. For a description of the rules and fallacies please consult van Eemeren and Grootendorst (2006). The figures 5 and 6 represent two moments within the session for which identifying elements, learning process acts and critical discussion acts are analyzed simultaneously.

In Figure 5 the following can be noted: between minutes 22:00 and 23:12 inconsistent assessment as a learning process act corresponds with the conceptual-cognitive statement of inappropriate support of the ASAC identifying element and to the fallacy of rule 7 of Pragma-dialectics known as *Secundum quid* (hasty generalization); between minutes 24:00 and 25:00, the request for clarification learning process act corresponds with the epistemic statement of data evaluation and with rule 1 (of freedom); between minutes 26:00 and 27:00 inconsistent assessment as a learning process act again corresponds with the conceptual-cognitive statement of inappropriate support from the ASAC identifying element, with the epistemic statement of data evaluation and the fallacy *Secundum quid* (hasty generalization) from rule 7.

In Figure 6, the following, can be observed: between minutes 50:00 and 50:30 inconsistent assessment as a learning process act corresponds with the conceptual-cognitive statement of inappropriate support of the ASAC identifying element, with rule 1 (of freedom) from Pragma-dialectics and with the Secundum quid (hasty generalization) fallacy from rule 7; between minutes 50:40 and 51:10, the clarity of part of the group (partial clarification) as a learning process act corresponds to a statement of inappropriate support from the ASAC identifying element, with rule 1 (of freedom) and with two fallacies (from rules 2 and 7): *Argumentum ad verecundiam* (avoiding the burden of proof), and *Secundum quid* (hasty generalization).

These parallel analyses between the learning process acts, the ASAC identifying elements, and the rules and fallacies of Pragma-dialectics have the purpose of demonstrating the close correspondence between three types of acts: those of learning process, those of the argumentative process in the classroom and those of critical discussion. This brings us to the point of putting forward a proposition: compliance with the rules of critical discussion proposed by Pragma-dialectics promotes argumentative development in the science classroom and in science learning. We will continue to work on this postulate.

Learning Process Act	Frequency
Partial clarification	7
Conclusion	3
Confusion	8
Skepticism	1
Assessment	4
Inconsistent assessment	8
Interpretation	16
Opposite positions	7
Claim of foundations	10
Request for clarification	13

Table 6. Learning Process Acts in Session 3

Speech Acts	Frequency
R1 (of freedom)	64
R1_f	2
R2 (burden of the proof)	1
R2_f	1
R3_f (of viewpoint)	3
R4 (of relevance)	12
R6_f (of starting point)	1
R7_f (of argumentation scheme)	21
R9 (of closing)	2
R10_f (of use)	5

Table 7. Speech Acts from the Critical Discussion in Session 3

Fallacy	Frequency
Argumentum ad misericordiam_10 (R1_f)	2
Argumentum ad verecundiam_13 (R7_f)	2
Argumentum ad verecundiam_13a (R2_f) o (R7_f)	1
Avoiding the burden of proof_32 (R6_f)	1
Straw man_26 (R3_f)	3
Secundum quid_22 (R7_f)	19
Vagueness_34 (R10_f)	5

Table 8. Fallacies in Session 3

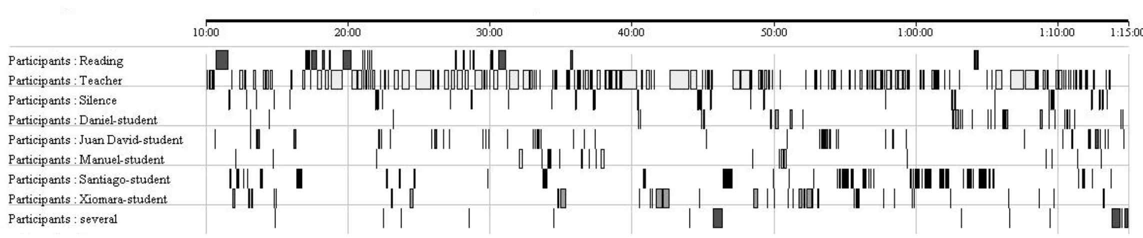

Figure 1. Timing Diagram for Participants' Interaction in session 3

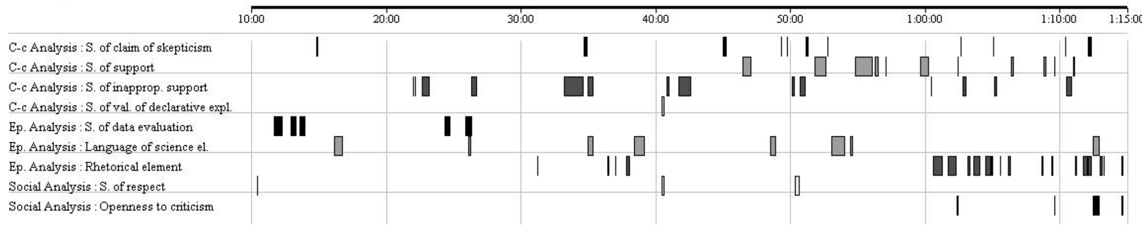

Figure 2. Timing Diagram for Identifying Elements from the ASAC in session 3

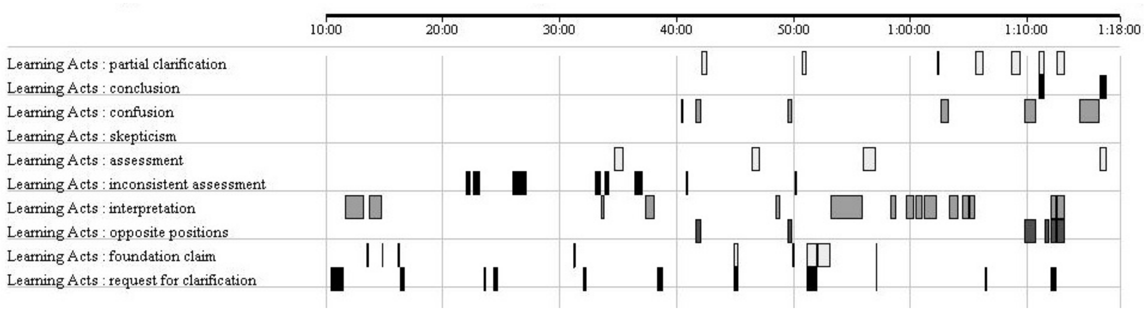

Figure 3. Timing Diagram for Learning Process Acts in session 3

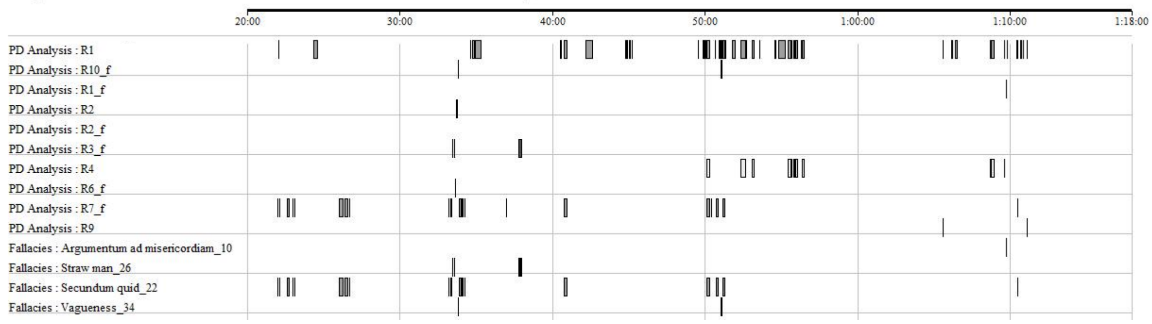

Figure 4. Timing Diagram for Acts from Critical Discussion in session 3

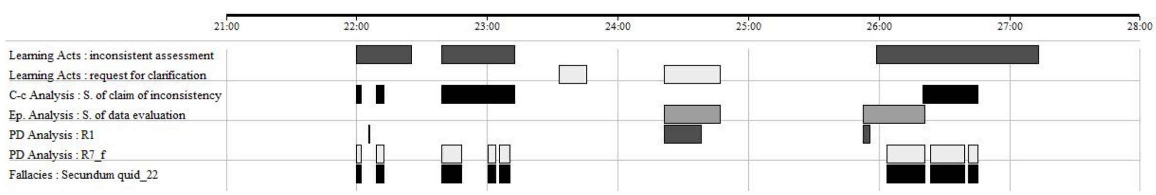

Figure 5. Identifying Elements, Learning Process Acts and Speech Acts and Fallacies for a First Period of the session 3

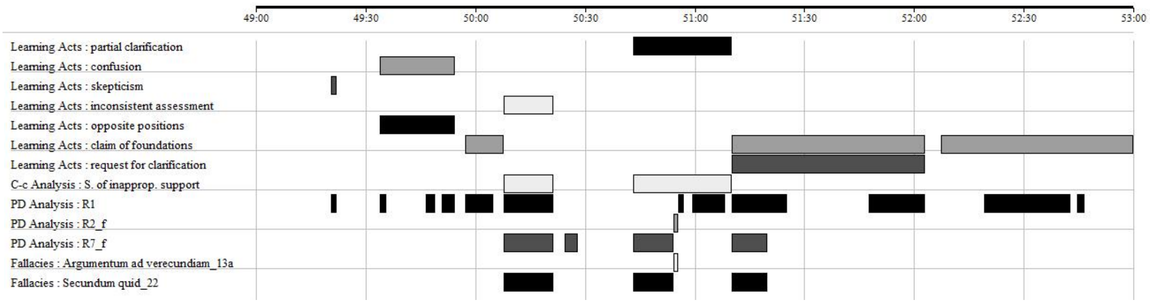

Figure 6. Identifying Elements, Learning Process Acts and Speech Acts and Fallacies for a Second Period of the session 3

4. CONCLUSION

The patterns of argumentation acts, during a pedagogical exercise in the classroom as an activity to promote knowledge construction, has been put forward. This exercise also provides teachers with the opportunity to receive information from students, recognize their previous ideas, discover their points of confusion, know what their interpretations are, clarify their concerns, pay attention to their claims for foundations, and evaluate their assessments.

Three ways to assess the argumentative process in the classroom have been proposed: 1) through the definition of identifying elements which have been obtained from the ASAC protocol; 2) through the definition of learning process acts; and 3) through the critical discussion of the Pragma-dialectical rules. An analysis using these three pathways has been presented for one session.

The following proposition is postulated: compliance with the rules of critical discussion put forward by Pragma-dialectics promotes argumentative development in the science classroom and in science learning. If it is assumed that there is a relationship between argumentation in everyday communication and argumentation in science, we propose that argumentative analysis proposals such as Walton's (Walton et al., 2010) or van Eemeren's (van Eemeren et al., 2000) should be included. Walton has categorized many presumptive schemes, arguments that contain factors that permit rebuttal (Ureta, 2010). For example, Duschl et al. (Duschl, 2008a) used nine of Walton's presumptive schemes in the SEPIA project (Science Education through Portfolio Instruction and Assessment). According to Duschl (2008a), such schemes fitted quite well with the students' structure and sequential reasons. However due to some difficulties in classification it was decided that the nine schemes would be divided into four categories: 1) arguments about a request for information –arguments from sign, arguments of commitment and arguments about position to know-; 2) argument from expert opinion; 3) arguments from inference –arguments from evidence of hypothesis, arguments from correlation to cause, arguments from cause to effect, and arguments from consequences-; 4) arguments from analogy.

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