Organic Chemistry Lectures in Higher Education and Pedagogical Link-Making

Ana Luiza de Quadros

Laila Thayanne Gomes de Almeida

Mariana Gonçalves Dias

Federal University of Minas Gerais
Brazil

Abstract

The curricula of undergraduate courses have been receiving criticism due to fragmentation of knowledge. In this study, we analyze the use of pedagogical link-making in Higher Education as possibility to reduce this fragmentation. For this, we have selected six professors who teach Organic Chemistry for several undergraduate courses, three of whom with more than 60% of students approved in disciplines and three others with less than 60%. We filmed and analyzed a set of lectures aiming to identify the links made to provide continuity to the content and to help students in the knowledge building in the classroom. Data analysis shows that professors make few macro continuity links, which can be a result of the little knowledge on the curriculum as a whole. Moreover, we observed that students are more successful with professors that make more pedagogical link-making, leading us to argue that these links help in the understanding of the "scientific story".

Keywords: Pedagogical link-making, Higher Education, Chemistry.

1. Introduction

Historically, lectures from Higher Education have been characterized by the organized transmission of information and experiences that, to the professor, are already consolidated. With this, it is expected that students retain these information, reproducing them in evaluation tools and, consequently, whenever they may be needed, throughout their lives. The technical character of many disciplines together with the more specialized education compared to Basic Education, end up enhancing the compartmentalization of knowledge, decreasing the link between them.The contemporaneity and the accumulation of knowledge have contributed to increase the compartmentalization of knowledge in undergraduate courses. The student, when entering the undergraduate education, comes across knowledge fragments that constitute an integrated whole. However, to perceive this integration has been shown to be a complex task, especially if the professor does not encourage this perception.
Several researchers (Peleias et al., 2011; Nicolini, 2003; Abbel, 2007) have highlighted the lack of interlinks between the different disciplines that constitute the curriculum and the little familiarity of professors with the *curriculum* as a whole.

Considering the need of the student to relate the knowledge with several educational areas and with the context (social, scientific and/or professional), we know to be indicated for professors to make these links; and for that, they need to be familiar with the curricular organization. Thus, we seized the proposal developed by Scott, Mortimer and Ametller (2011) considering what they called pedagogical link-making, to analyze the lectures of a group of professors of the Higher Education, who lecture Organic Chemistry. Scott, Mortimer and Ametller (2011) developed the notion of pedagogical link-making of content, referring to the forms in which professors and students relate ideas in the classroom, for the construction of knowledge. These authors consider that the pedagogical links are fundamental to the teaching and learning of Sciences and state that knowing them can provide professors the reflection and analysis of their own teaching practice.These authors used Vygotsky (2010) as a basis, who considers learning in two main planes. First in the social plane – through discussion of ideas – and second in the individual plane – when the subject internalizes a new idea. The new idea will only be internalized when it makes sense for that subject and this "make sense" depends on existing ideas and the ability to connect these ideas.In Figure 1, we synthesized the pedagogical link-making proposed by Scott, Mortimer and Ametller (2011).

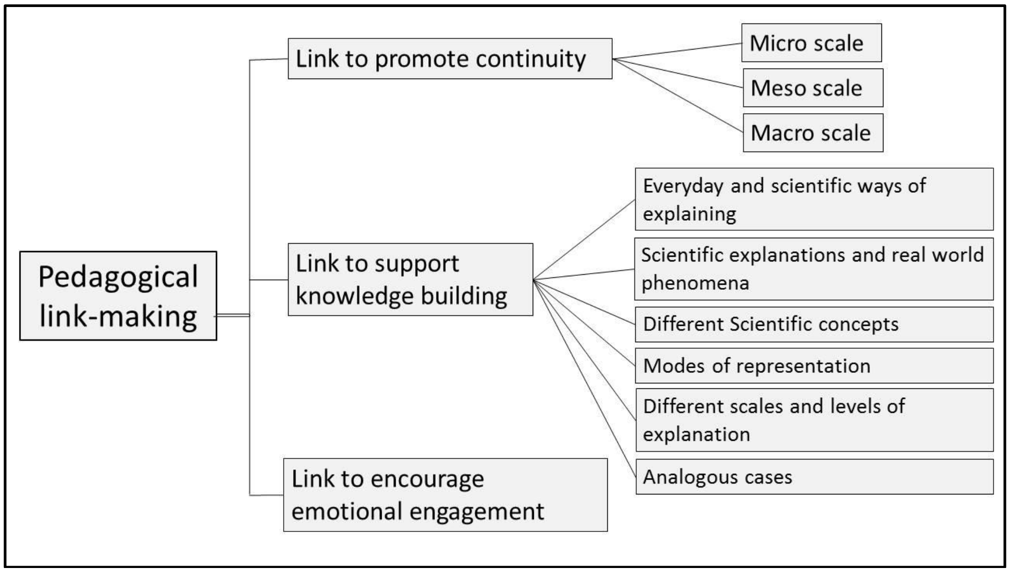

Fig. 1 – Pedagogical link-making proposed by Scott, Mortimer and Ametller (2011).

The first form of pedagogical link-making – **Link to promote continuity**– involves events and concepts separated in time. Teaching, held by a temporal sequence of concepts, forms a whole which authors name “scientific story”. So, students do not lose the sense of the “story”, the professor must promote the continuity, which may involve several strategies. Pedagogical link-making to promote continuity were proposed in three levels:

a) Macro: continuity links made on an extended time scale (typically of months/years), which involve making references to different parts of the science curriculum. In the case of higher education, we considered as macro links the one held between contents that extrapolate the discipline of the professor (other disciplines, for example).
b) Meso: continuity links made on an intermediate time scale (typically of days/weeks), which involve making references to different points within a lesson sequence. In this case, we considered as meso link the moments when the professor relates different contents within the discipline he/she teaches.
c) Micro: continuity links made on a short time scale (typically of minutes), which involve making references to different points within a lesson. To set this type of link, we considered those made within a class.

For the second form of pedagogical link-making – **Link to support knowledge building**– the authors elect six approaches, all addressing the possible links between different natures of knowledge: every day and scientific ways of explaining, scientific explanations and real world phenomena, different scientific concepts, modes of representation, different scales and levels of explanation and, finally the analogous cases. We started to synthesize them:

a) Links between everyday explanation scientific explanation – the scientific concepts are products of specific scientific communities and are part of the knowledge developed in the classroom, while the everyday knowledge is the one generated based on observation of natural factors and facts experienced, which is usually applicable to a context or phenomenon and cannot be generalized. These links are made both to integrate and to differentiate the everyday and scientific ways of explaining.
b) Links between scientific knowledge and the phenomena – when not linking a concept to real world phenomena, this concept can become, for the student, a set of explanations and generalizations with no practical foundation. The link between the scientific explanation and the phenomenon has the function of linking the scientific ideas with the world, through specific phenomena, representing a potential of interest and relevance. These phenomena can be created or brought into the context of the classroom.
c) Link between scientific concepts – the authors argue that to learn scientific concepts involves recognizing how these scientific concepts fit into a broader system. Just as it is important to relate a concept with its reference object, it is also important to relate it with other concepts involved. As an example, we can use the case of activation energy.

This concept is directly related to the concepts of heat, chemical reaction, reactants and products, chemical bonds and others. To promote the understanding of the concept in question, it is indicated for the professor to make this link between the several concepts involved.

d) Modes of representation – the authors used Lemke (1998) as a basis, who draws attention to the fact that current science uses not only the verbal language, but also a mathematical, graphic, pictorial language and a number of other modes to represent a same substance or material. Considering Chemistry, chemical formulas and models represent very specific modes of communication. For Scott, Mortimer and Ametller (2011), developing a deep understanding of scientific concepts implies the ability to relate different modes of representation.

e) Different scales and levels of explanation – for Scott, Mortimer and Ametller (2011), the knowledge has as basic feature the fact that it can move between explanations set at different scales of magnitude, some of which are not directly visible to the observer. These levels are based on Johnstone (1991) and can be summarized in symbolic, sub-microscopic and macroscopic.

f) Analogous cases as form of link-making – in this type of link, the professor helps the student to understand a concept by making analogy with a more accessible or familiar case. Analogy is a comparative process of different phenomena and models through their similarities or a link of similarity established between two or more different entities.

The third form –**Pedagogical link-making to encourage emotional engagement** – focuses on affective and emotional aspects. According to the authors, the professor can make use of some strategies that engenders positive emotional responses of students, which generates a good mood in the classroom, certainly favorable to learning. Among these strategies, there are the ones with more affective character (referring to students by their name, listening to what the students have to say about a fact or phenomenon studied in class, respecting the students' point of view, praising the student when a compliment is fit, etc.) and to help in the understanding of the scientific story, through pedagogical link-making. We believe that, when conducting pedagogical link-making to promote continuity and support to knowledge building, the professor will be already encouraging the student's emotional development.

Several papers have been published based on research using the pedagogical link-making proposed by Scott, Mortimer and Ametller (2011). We selected two that involve undergraduate students (Colucci-Gray et al., 2013; Wood et al., 2014), one involving students of Basic Education (Rocksén and Clas, 2017) and three involving teachers who develop classes in Basic Education institutions (Haug; Ødegaard, 2014; Murcia, 2014; Junjun; Bronwe, 2013).

Colucci-Gray et al. (2013) investigated students' ideas on evolution (organisms and cells). For this, they used the materials produced in a discipline of about 30 h, with first-year undergraduate students in Biology and did the survey of conceptions concerning organisms and cells. Afterwards, they shared/discussed systematically these data with the participants, focusing on conceptual understanding, in dialogic activities. In addition to other arguments, they defend that the links between the scientific explanations and everyday explanations and, also, between different levels and scales contributed to the evolution of the conceptions that these students had compared to the concepts worked on the course/discipline.

Wood et al. (2014) conducted a study involving undergraduate students in Physics from an institution of the United Kingdom. For that, they used three categories, one of which was a pedagogical link-making proposed by Scott, Mortimer and Ametller (2011). It was a context in which the study was conducted using the material made available online and students attended a weekly class, more like as solving problems and exercises. When recording the students' lines and confronting them with the answers provided in the evaluation tests, the researchers reported that two forms of pedagogical link-making (Scott, Mortimer and Ametller, 2011) were found in the dialogues. The first of them refers to the link between the concepts and the second to the scientific concepts with real life phenomena.

In an Elementary School from Sweden, Rocksém and Clas (2017) investigated a ninth-grade class, videotaping the classes for 4 weeks. They investigated the dialogues between professor and students and between students of two groups, classifying them into: micro scale when references were made during the conversations that took place in the same lesson; meso scale when references were made to past lessons and future lessons within the unit; and macro scale when references were made to previous and future conversations that extrapolated the unit analyzed.

The authors state that the verbal and textual references were used by both the professor and the students, which made the interaction more intense. However, the temporal relations in macro scale were less present. With that, the authors restate the importance of investigating these links, to make them more fruitful, improving the understanding of how science professors develop learning experiences.

Chen e Cowie (2013) investigated an elementary school teacher, who developed a sequence of lessons on native birds, in New Zealand. After the development of the classes, which lasted about five weeks, the teacher attended an assessment meeting with researchers and eight students were interviewed to identify the learning. For the researchers, the students' lines indicated clearly the great value of a sequence of classes based on pedagogical link-making, especially those that assist the student to relate scholar concepts with situations beyond the classroom.

Murcia (2014) investigated two classes of Science teacher, in which the IWB (interactive whiteboard) technology was used. Noting that the meaning construction is not on the technological artifact, but in the use that the professor makes of it, she focused on the interactions and pedagogical link-making built in these learning environments. With that, she noticed that the pedagogy of teacher was not focused only on interactive technology, but also in promotion of interaction between students, which explored actively the scientific conceptions in multimodal formats and made innumerable pedagogical link-making.Haug and Ødegaard (2014), on its turn, investigated 6 teachers of Basic Education, focusing on how these teachers facilitated the learning of concepts of their students and how they encouraged them to use key concepts, when talking and writing about situations different from those worked in the classroom. Given this context, they also investigated the strategies used by teachers to create pedagogical link-making, also important for the understanding of the meaning of a concept. The authors suggest that conceptual learning occurs only when students apply the key concepts, and that the understanding is not promoted when teachers speak only, rephrasing the students' lines or presenting the correct explanation. For them, the creation of pedagogical link-making is essential, because students learn when they make these links.

Other equally important surveys have been developed involving the teaching and learning of Mathematics in initial grades (Venkat; Naiddo, 2012), the use of drama/theater to teach Sciences (Braund; Ekron; Moodley, 2013; Braund, 2015), the and links made by students as teaching and learning moments (Haug, 2014) and the processes of problem solving in the classroom through the dialogue (Kim; Roth, 2014). In High School, three other studies were conducted involving these links (Strømme, 2015; Dierdorp et al., 2014; Ummels et al., 2015). Another involves the links of content made in undergraduate lectures in Physiotherapy (Nurkkaa et al., 2014).

In this study, we drew our attention to Organic Chemistry lectures of professors in Higher Education, because they deal with knowledge of great level of abstraction. We were based on the hypothesis that in this level of education there is a greater tendency of prioritizing the conceptual organization and little attention to pedagogical link-making.

2. Methodology

We selected six professors responsible for disciplines of Organic Chemistry, from the Department of Chemistry/ICEx, from the Federal University of Minas Gerais. This selection considered three professors among those in which the approval rating is generally high in the disciplines they offer and three others in which the approval ratings of students is generally lower when compared to the other group. For that, we held a survey on the performance of students in the disciplines of Organic Chemistry of three academic semesters. With this result, we invited the professors to participate, until we got to the set of three professors from each group. Table 1 shows the performance of students in classes that were object of analysis.

Table 1 – Performance of students in classes of professors investigated.[1]

Professor	Discipline	Students enrolled	Approval (qty.)	Approval (%)	Approval rate
Prof. 1	Organic Chemistry II	27	17	62.9	72.4
	Organic Chemistry I	25	21	84	
	Organic Chemistry I	37	26	70.3	
Prof. 2	Organic Chemistry II	40	24	60	61.25
	Organic Chemistry I	32	20	62.5	
Prof. 3	Intro. Biochemistry	53	41	77.36	62.21
	Organic Chemistry I	51	24	47.06	
Prof. 4	Organic Chemistry I	47	25	53.2	49.3
	Organic Chemistry I	44	20	45.5	
Prof. 5	Organic Chemistry I	36	20	55.5	53.45
	Organic Chemistry I	35	18	51.4	
Prof. 6	Organic Chemistry II	21	9	42.9	42.6
	Organic Chemistry II	26	11	42.3	

Source: Class record book given by the professor to the institution.

We considered a percentage of 60 to split professors into two groups, because it is the standardization used in the institution where this research was held, for approval of students. In the case of professor 3, due to a matter of institutional organization, he was not responsible for disciplines in the two subsequent semesters. Thus, we considered two disciplines lectured in the semester in which we started data collection. Therefore, one of the disciplines of Prof. 3 is Introduction to Biochemistry and not Organic Chemistry. But we believe that the large number of students in disciplines under his/her responsibility counterbalances the fact that one of them is not Organic Chemistry. It is noteworthy remembering that Introduction to Biochemistry is responsibility of professors in the sector of Organic Chemistry, in the Department of Chemistry of the institution concerned.

After serving the legal procedures, we filmed a set of lectures from each of these professors, in the natural environment in which they happened. These lectures were analyzed and, for this study, we selected one lecture (100 minutes) that represented the other lectures of this professor. We built maps of episodes and analyzed the continuity links (micro, meso and macro) and the links to support knowledge building. We understand that, in the case of Higher Education, the links that take into consideration the different levels or scales could have overlapped the links between scientific and everyday explanations or between scientific explanations and phenomena and, thus, we chose to exclude them from the analysis. Instead, we used the link between scientific knowledge and its application, since it is common to the professor of Higher Education to relate the knowledge taught with the production and use of technological artifacts. This form of link seems to have the function of making the concepts to become instruments of thought on the objective world of students. Thus, to confer meaning to a scientific concept involves, also, to recognize the application of this concept. Therefore, the links to support knowledge building used in this research were: scientific and everyday ways of explaining; scientific explanations and phenomena; between concepts; scientific explanation and application; modes of representation and analogies.

To facilitate the analysis, we defined the **micro** continuity links as the ones held between concepts studied in a same class. We named **meso** the links made between contents studied within the discipline. As for **macro**, we considered those in which the professor links the content on study with another discipline, another field of knowledge or even with contents of Basic Education. In one single case there was a link with contents that would be studied in the future, which we were unable to classify, because we did not identify when the content referenced by the professor would be studied. We chose to exclude this link. For links that aim to support knowledge building, we considered the link between science and everyday the situations in which the professor refers to something that is part of the context in which students are part of. In the link between science and one phenomenon, we considered the moments in which the professor creates or refers to a phenomenon, to associate it with the content. The link between concepts occurred when the professor explained the concept that he/she

[1]The professor of Department of Chemistry/ICEx, fromat Federal UniversityofMinas Geraishavethepracticetotakethesametest for all classes ofstudents, in thesame semestre.

intended to develop and, to explain it, he/she brought a broader conceptual network, showing how the concepts are related. To analyze the modes of representation, we chose to consider the cases in which the professor uses more than one mode simultaneously. This happens, for example, when the professor draws a chemical structure on the board and compares it with a representation built using ball-and-stick model. In addition, the links between concept and application and analogies were analyzed.

When showing data and their analysis, we chose to identify professors through abbreviation "Prof.", followed by a number (Prof. 1, Prof. 2, etc.), intending to assure the anonymity. In this case, Prof. 1, 2 and 3 are those in which the number of students successful in their disciplines is greater than students successful in the disciplines of Prof. 4, 5 and 6. For that, we considered that students who have had enrolled, but at some point abandoned or failed the discipline, had not been successful (Table 1).

3. Results and Discussion

In this section we present initially the quantity of links made by professors, individually and, subsequently, the distribution of these throughout the class, through charts. Table 2 shows the continuity links that we perceived in lectures of each professor. This table provides only the number of links made by professors, not taking into consideration the moment of the lecture in which each one of the links was used.

Table 2: Continuity links made by the six professors in 100 minutes of lecture.

PROFESSOR	CONTINUITY LINKS		
	MICRO	MESO	MACRO
Prof. 1	3	14	0
Prof. 2	4	9	2
Prof. 3	4	10	3
Prof. 4	2	9	1
Prof. 5	0	9	2
Prof. 6	3	3	1

Meso continuity links, which deal with the link the professor makes between the contents of his/her discipline, provide cohesion to the speech, because they relate elements of the discipline, throughout the 4 months in which they usually last. We can observe that all professors made these links, in addition to be the most frequent. As for micro continuity links, responsible for a coherent speech throughout a single lecture, we perceived that not all professors make it. It was more recurrent between Prof. 1, 2 and 3, although the difference was not very significant. On macro continuity links, which link the content under study with contents from other disciplines or other fields of knowledge, we perceived a low frequency from all professors. Data show us two very significant tendencies for this group of professors. The fact that micro continuity links are little made can be an evidence that professors feel no need of relating contents developed in a short period of time, as in the 100-min lectures. However, the process of meaning-making on what is studied in the lectures may depend on these links and, therefore, the most indicated would be that they were rather made by the professor than wait for students to make it by themselves. As a second tendency, we noted the low number of macro continuity links. In this case, what seems to be more explicit is the little knowledge that the professor has of the *curriculum* as a whole. To make links with what is studied in other disciplines of the curriculum framework, the professor needs to know in depth this framework. Organic chemistry disciplines examined here are offered for various courses within the institution, with no requirement for the professor to focus on the curriculum of these courses. The organization of the institution causes the professors to be allocated according to fields of knowledge, both for teaching and learning and for research. Therefore, it is not linked to a specific course, which decreases the professor's possibility of knowing the curriculum framework of the course for which he/she lectures disciplines. Considering the lectures analyzed, the fact that macro continuity links rarely happen probably results from this distance of the professor to the course and the little attention, given the importance of these links for the understanding of Science as a whole. If these links do not happen, it is likely that the student continues receiving fragments of knowledge that he/she cannot relate. On the links that support knowledge building, Table 3 shows us the links and the number of times that they appeared in each lecture.

Table 3: Links to support knowledge building, made by the six professors in 100 minutes of lecture.

PROFESSOR	LINKS TO SUPPORT KNOWLEDGE BUILDING					
	Science and Everyday	Science and Phenomenon	Science and Application	Between concepts	Modes of Representation	Analogies
Prof. 1	1	1	4	8	3	1
Prof. 2	1	0	2	1	9	1
Prof. 3	13	2	1	1	0	6
Prof. 4	0	0	1	0	3	0
Prof. 5	3	0	2	0	1	0
Prof. 6	1	0	1	0	1	0

According to Scott, Mortimer and Ametller (2011), these links become part of the pedagogical interactions that provide the student the support necessary to give meaning to the concepts studied in the social level. Therefore, they are important, so students can have a deep understanding of these concepts in the individual level. Although we cannot generalize among all professors investigated, it is possible to perceive significant differences. For links between Science and Everyday, Science and Application and Modes of Representation, we can perceive that Prof. 1, 2 and 3 make them in larger numbers when compared to the other three. However, it is in the links between Science and Phenomenon, between the concepts and the building of analogies that the difference became more significant. Prof. 4, 5 and 6 made none of these links in 100 min of lecture.

Between the Prof. 1, 2 and 3 we see typical characteristics that show an effort to provide meaning to what they are teaching. Prof. 3 outstood in number of links that he made in Science with Everyday; Prof. 2 outstood in simultaneous use of different Modes of Representation; and Prof. 1 outstood in links made between the different concepts. For the other three we could not find something that highlights them in terms of pedagogical link-making that assist knowledge building.

In general, we can state that Prof. 4, 5 and 6 made far fewer links during the 100-minute lecture compared to Prof. 1, 2 and 3. We know that Organic Chemistry disciplines, generally, deal with more abstract contents, to which these links are not favored. However, Prof. 1, 2 and 3 show that these links are possible. In the case of this sample of professors, when compared the result concerning the analysis of lectures with the success of students, we observe a directly proportional link: the more pedagogical link-making are built during the lecture, the greater the success of students.

We believe that there is little attention for the need of these links in lectures. If these disciplines were planned considering the insertion of pedagogical link-making, these numbers could increase significantly, which could assist in student's understanding on what is taught in lectures and on the course as a whole.

3.1 How links happen through time

We considered important to clarify how the pedagogical link-making are distributed throughout a lecture. To exemplify, we chose to consider the micro and macro links, throughout the duration of a lecture, for the six professors. Figure 2 shows the chart with these links.

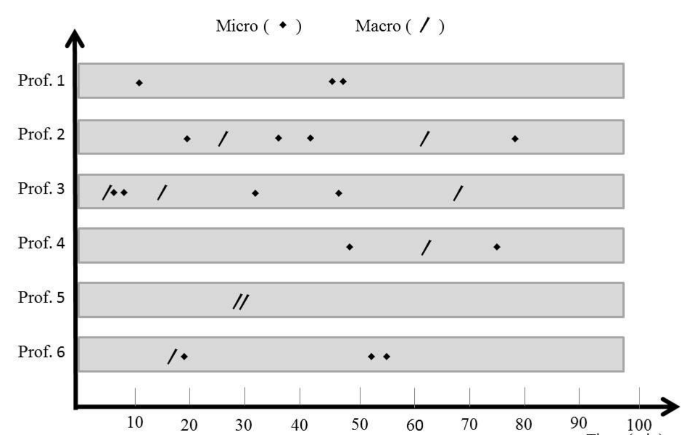

Fig. 2: Chart with distribution of continuity links throughout the lecture, for each professor.

For micro and macro continuity links, we can perceive that they were distributed throughout the lecture, although this became more visible only for Prof. 2 and 3. It was not possible to perceive a moment of the lecture in which these links outstood.

The fact that we found few macro continuity links (/) leads us to state that the attention of these professors is more directed to the discipline they teach than to the *curriculum* as a whole. With it, they leave under the students' responsibility the links of contents, which may not happen. The links perceived represent a strong evidence that these professors seek to relate the contents/concepts taught by them, but not other disciplines. We made a chart for links that support knowledge building, with the links between Science and Phenomenon, between the concepts and with the Analogies, for example. These links were built only by Prof. 1, 2 and 3. Figure 3 show the distribution of these links throughout lectures.

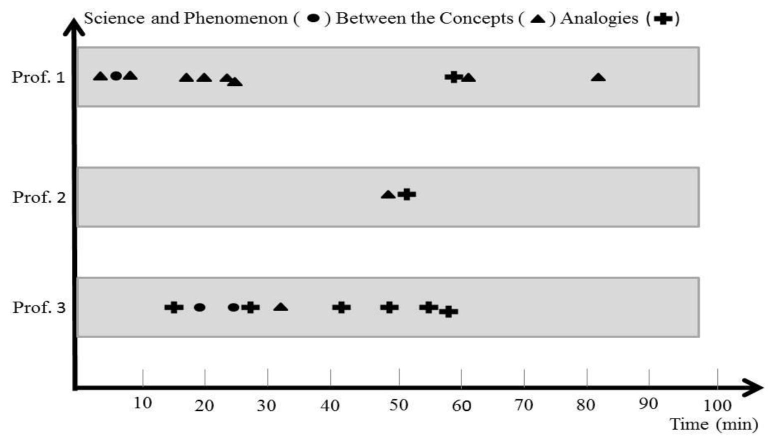

Fig. 3: Chart of distribution of the links between Science and Phenomenon, between the concepts and Analogies, for each professor.

We can note that the links between Science and Phenomenon appear in the beginning of the lecture of Prof. 1 and 3, likely to draw attention of the student on the importance of the content that will be studied throughout the lecture. In the rest of the lecture, however, they are not used. The analogies and links between the concepts happen at different times of the lectures. Considering that these three professors were the only ones to make these types of links and that the number of students successful in their disciplines was higher compared to the other three, we can infer that these links assist students is the process of signifying the content and, therefore, in learning.

4. What do these links tell us about the lectures?

As argued, when students enter the undergraduate education, they go through a set of disciplines whose contents not always dialogue between themselves, despite composing a whole. Therefore, to perceive this integration can become a complex task for students and, accordingly, requires attention of professors. Our hypothesis is that the continuity links can promote a wider view of the curriculum, as the student perceives that a content studied in one discipline is directly related with the content of another discipline or that different contents of a same discipline are related. Even within the same lecture it is shown to be important. Rocksém and Clas (2017) had already reported the little presence of continuity links in macro scale regarding students. Due to data obtained, we perceived that the professors also little perform this type of link. If there is no effort of professors in the sense that the concepts throughout a course are seen as part of a whole, through macro continuity links, it is most likely that students are unable to make it.

The links to support knowledge building are equally important, by promoting the signification of content. They were more frequently built by professors of disciplines whose students are more successful. Most likely these links that the professor made in the social level (classroom) facilitated the appropriation of what was taught, contributing for the students' success. In studies developed by Colucci-Gray et al. (2013) and Wood et al. (2014) it was clear that students need to make link-making of the content developed in lecture with situations that go beyond the school, to relate the concepts to each other and that it is done using multimodes.

Results found by Berit and Ødegaard (2014), Murcia (2014) and Chen and Cowie (2013), when investigating professors who perform pedagogical link-making, showed that students learn more when these links are present in lectures. These results meet the arguments of Scott, Mortimer and Ametller (2011), mainly that to relate ideas in the classroom helps in the building of meanings to what is studied. When looking to the data produced based on the analyses of lectures of professors of Higher Education, we perceived that professors whose students are more successful make more both continuity and knowledge building links. Although we used a reduced sample of professors, data represent a strong evidence that these links indeed help the student on the understanding on scientific concepts studied in class, contributing for his/her success in the discipline. We are in full agreement with Scott, Mortimer and Ametller (2011), when they state that the pedagogical link-making approaches are fundamental to the teaching and learning of sciences, and, still, that to know them can provide professors the reflection and analysis of their own teaching practice, which leads them incorporate these links.

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