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Investigating Courses of Undergraduate Students in Physics Education Through the Interdisciplinary Island of Rationality (IIR): Cutting Out of a Case Study

Carlos Mometti
(School of Education, University of São Paulo, Brazil)

Abstract: In this work, we propose an investigative study of the didactic strategies that undergraduate physics students at the University of São Paulo, campus of the capital, designed to implement an Interdisciplinary Island of Rationality (IIR) activity in high school. We will present the results for one of the three interventions studied. Data collection occurred simultaneously with the planning and execution of this island and took place throughout the mandatory curricular internship of these undergraduates in the discipline of the Methodology of Teaching Physics II. Furthermore, the pedagogical strategies used were analyzed from a sociological and cultural lens based on the theoretical perspectives of Sewell Jr. (2005), in addition to the methodological definitions of IIR developed by Fourez (1992; 1994; 2001). We could notice that the change of methodology to approach interdisciplinarity caused in the undergraduate's difficulties in the development of their teaching strategies, besides producing reflexes in the didactic culture observed during their internships.

Key words: physics education, interdisciplinary approach, teacher training, teaching methodology

1. Introduction

Interdisciplinarity is a theme that raises many discussions between teachers from the most varied disciplines. Its definition goes through several perspectives and its importance is justified by the expectation of introducing a different methodological approach in teaching. The latter being, according to the main contemporary studies in the area, the search for an integration between the disciplinary contents. However, the didactic-pedagogical difficulties that science teaching (ST) has been presenting in recent years and, especially, the physics education (PE) with regard to the integration of various disciplinary contents are notable.

In this way, adding to the pedagogical practice of physics in high school, only citations of conceptual knowledge from other disciplines will not, in a way, cause any process of significant change in its teaching. Since it creates the illusion of innovative teaching with products that result from that traditional saying.

Another crucial point that should be highlighted — which adds to the students' learning difficulties in physics — is the fragmentation of knowledge, which is becoming more prominent every day, due to the result of the optimization and development of scientific and technological knowledge, as well as the intensification of the

Carlos Mometti, Ph.D. Student, School of Education, University of São Paulo; research areas: physics education, teachers training. E-mail: carlosmometti@usp.br.

globalization process that we have been going through in the current century.

In fact, the existence of many topics in a planned curricular structure with few classes in the scientific disciplines becomes an impediment to many of the essential actions of the teaching process. For, since the referred fragmentation, not favoring the integration between the different themes and concepts, ends up demanding a long time to work, separately, each aspect of knowledge.

With this, the student is favored in his/her insertion in the scientific and technological world, appropriating the necessary knowledge for his/her survival and critical development in a century in which technologies are part of our daily life. Technologies that go hand in hand with science and were not created/developed in isolation with regard to areas of knowledge.

In short, the greater articulation between the concepts of the various disciplines has the potential to contribute to students' more integrated understanding of the contents taught, in addition to enabling them to understand that knowledge is not compartmentalized or "disconnected", making them subjects literate scientifically and technologically.

In addition, new methodological proposals for working with ST have emerged over the past few years, among which we can mention the Interdisciplinary Island of Rationality (IIR) proposed by Gerard Fourez (1992).

In view of the aforementioned IIR perspective, this presupposes the confrontation of interdisciplinary issues, through projects, linked to everyday problem situations. In addition, it has the intention of seeking solutions for the fragmentation and decontextualization of scientific knowledge, established in the school disciplinary model.

However, taking as a study context the internship of physics graduates at the University of São Paulo, campus of São Paulo, we are faced with a relevant question to think about the teaching practice and that, in a way, motivated us to this investigation: how do physics graduates from a disciplinary background deal with new teaching strategies during their pedagogical practice in the internship?

Such a question proved to be broad when we think about the pedagogical practice of a future teacher, since the new strategies are thought and worked throughout his initial formation and, also, they can give us a false generalization, being that each classroom has a diverse reality.

Furthermore, reflecting on the teaching practice of these graduates and restricting our study lenses to a specific group of interns, we asked ourselves the following question: what didactic strategies are used by such interns in the development of interdisciplinary projects based on IIR methodology in high school?

This question is the central point of our research, and this work presents only a section of the entire study.

2. Theoretical Approaches

In order to contribute to the motivating question of this research, we proposed a path that allowed us to study the didactic practices of physics teachers in initial training. In particular, we seek to understand these didactic practices in the teaching of physics, as practices associated with a social subsystem whose engine is the search for the learning of its concepts, laws, principles, and techniques by the students of a certain class.

We will characterize these teaching practices as a dyad, which consists of action schemes and resources that teachers use during the teaching/learning process.

For a better characterization of what we mean by action schemes and resources, we will adopt the definitions proposed by Sewell Jr. (2005). This author starts from a reformulation of the structural theory initially proposed by Anthony Giddens, an American sociologist who developed a theory of structuring in the 1980s.

In this reformulation, he argues that the structure operates in the discourse of social science as a powerful mechanism, identifying some part of a complex social reality as an explanation of the totality [social body, emphasis added] (Sewell Jr., 2005, p. 146).

In this way, the term structure presents three theoretical problems that preclude its agreement as a properly defined and effective concept. The fact that in the sociological language the term structure is different from that used by the anthropological language, it is generated, still according to Sewell Jr. (2005), the establishment of a theoretical confusion about its definition. Thus, however problematic the notion of the structure may be, it dominates something very important in social relations: the tendency for the patterns of relationship to be reproduced, even when the actors involved in the relationships are ignorant of the patterns or do not want their reproduction (Sewell Jr., 2005, p. 148).

It is worth mentioning that the focus of our research is on the ways of acting for physics graduates. In this way, the classroom context becomes a privileged place of study because it is an environment where students and teachers live together, a space for the production of culture that we name, according to Pietrocola (2014) as a didactic culture. In addition, from the perspective of Sewell Jr. (2005), in social contexts, we observe overlapping cultures that permeate all the schemes of action involved as well as the resources associated with them.

In this sense, translating our motivating question, we are interested in studying the didactic strategies used by physics graduates, with regard to their action schemes and resources, when they used a different way of teaching from those they were used to and, mainly, from that in which they are formed, that is, the one related to a fragmented disciplinary structure. Such a different way constitutes the interdisciplinary approach brought by Fourez's IIR (1992; 1994; 2001).

Nevertheless, this teaching methodology proposed by the IIR stands out, basically, for two essential points: (a) it does not separate scientific knowledge from technological knowledge and (b) it integrates interdisciplinary knowledge in its development.

According to Fourez (1992; 1994; 2001), the IIR aims to achieve an appropriate theoretical representation in a precise situation and according to a specific project. This means that to develop knowledge using the IIR approach is, roughly speaking, to develop a theorization that fits the problem addressed, or taking the classroom as an example, on the subjects studied in physics in high school.

Furthermore, Fourez (1992; 1994; 2001) classifies the IIR in two categories, namely: (1) those that are organized around a notion and (2) those that are organized around a project. The second category guides the central object of our study. Thus, we will designate here as an IIR an interdisciplinary project consisting of a set of phases or steps to be followed around a problem initially proposed and applied to high school students.

The moment chosen to carry out this research is confused with the mandatory curricular internship performed by such graduates during their Physics Teaching Methodology II course, taught in the second semester of 2017.

3. Methodological Approaches

This study takes the context of the Physics Teaching Methodology II course developed during the second semester of 2017, at the School of Education at the University of São Paulo. And this choice is due to two important aspects, namely: the fact that this is a theoretical-practical discipline, containing part of its workload consisting of theoretical discussions about teaching/learning and supervised internship activities and, the second, the fact that the theme of teaching is based on the interdisciplinary strategy in the program.

According to Pietrocola et al (2003) and Nehring et al. (2000), adapted from Fourez (1992; 1994), the steps that constitute an IIR are step 1 (*cliché* of the proposed problem-situation), step 2 (elaboration a spontaneous overview), step 3 (consultation with specialists and specialties), step 4 (going to practice), step 5 (in-depth opening of the black boxes and discovery of disciplinary principles), step 6 (global design of the process), step 7 (opening the black boxes without the help of specialists) and, finally, step 8 (synthesis of the island produced).

In this perspective, the term "black box" is a representation of a part of the world, which is accepted in its entirety without considering it useful to examine mechanisms of its functioning, according to Schmitz & Alves Filho (2004).

In a succinct way, the first step aims to take students to a shower of initial ideas, that is, to express everything they understand by the proposed initial object. In the work developed with the group of subjects of this research, which we call here the phase of preparation of the intervention, they were guided to the elaboration of a proposal in the form of a public notice, which should contain the problem situation, the time of realization and the type of product that should be delivered at the end of the stages by high school students.

The second step, however, is responsible for filtering all ideas initially said and launched by the students in the *cliché* phase, where they seek to expand what will be studied, the points that are really relevant to the development of the work.

In the third stage, the experts, already listed in the previous stage, will be consulted and all the information collected will be taken to the group in order to incorporate them into the project. Later, in the fourth step, some of the members previously made available for this function will go to practice, see how it works, collect information, ways of doing it, etc.

Nevertheless, the sixth step is characterized by the global outline of the process, that is, the realization of a synthesis of what was done with the main points of the IIR, in addition to the specifications of the black boxes that can be opened by the educator.

Subsequently, in the seventh step, the black boxes are effectively opened without the assistance of specialists. This phase is extremely important, as it contributes to the development of student autonomy since we all build alternative concepts to explain phenomena that surround us, with strong elements of common sense.

However, as a methodological design in this study, we adopt the perspective of Tobin & Ritche (2012), which uses analyzes of recorded lessons and, subsequently, reconstructs the event that occurred during such filmed moments. This procedure is called an event-oriented theory.

In this perspective, we call it an event at all times that characterizes a change (be it on a *micro*, *meso*, or *macro-level*) in the structure of a specific social group Sewell Jr. (2005). Therefore, if we take the classroom as space where cultures are transformed and reproduced, an event could be something that happens at a given moment and differs from what was "used" to see in that environment with that group.

Finally, the notions of culture and the schemes of action and resources that are being used to study the practices developed by the undergraduates are those developed by Sewell Jr. (2005).

4. Discussion of Results

As previously mentioned, our research question focused on the didactic practice of undergraduate students in physics education. Specifically, with regard to the action schemes and resources spent by those during their interventions in the discipline of Physics Teaching Methodology II, a discipline that constitutes a mandatory

curricular internship in the undergraduate course in Physics at the University of São Paulo.

In this sense, the guiding principle for the beginning of our analyzes originated from a reflection on how teachers who are trained in a disciplinary structure reproduce and transform cultural practices in the classroom during their work. It should also be noted that, according to Sewell Jr. (2005), we consider the classroom as a space that generates cultures, which overlap each other, establishing social relationships and defining/characterizing standards for the social structure.

In addition, the classroom reflects the social world of which students are a part. Thus, any socially accepted and structured standard is taken, reproduced, and transformed for teaching-learning moments.

Regarding the source of information obtained for the production of the data, this was characterized by the video lessons recorded during the three interventions at the school, the audiences of the interns obtained from a recorder with a lapel microphone, the field notebook of the researcher with the observations throughout the process and, also, for the reports in the form of a narrative of the interns in the stage after the development of the internship.

Nevertheless, the data were produced from this set of information and were distributed in three moments of the research: *initial stage* (relative to the orientation of the interns about the IIR methodology), the *stage during* (moments of the application of the IIR prepared at school) and *later stage* (moment of reflection on the practices developed by the interns during their interventions through a written narrative).

In addition, as the interest of this work is in understanding how the schemes of action and resources of undergraduate students in physics take place when they use a methodological approach different from the one they are used to during their training (basic and higher), the analysis presented here will focus on a step during the process.

However, in order to corroborate the observations and build an understanding that is as close as possible to a complete answer to the research question, we used the initial and subsequent steps to complement the analysis.

The schemes of action and resources that the undergraduate students used to develop their practice in most of the moments of the three interventions could be categorized according to what Fourez (1992; 1994; 2001) understands by what is necessary for a teacher during an interdisciplinary practice. In this perspective, the following categories of analysis were obtained from Fourez (1992; 1994; 2001): *negotiation*, *content organization*, *discussion points manager*, *time manager*, and *constant update*.

Thus, the data obtained from the interventions were categorized according to the labels listed above and are presented in the form of moments (in minutes), which corresponds to the time interval of the video lesson that was recorded. In this work, we will present only the categorizations related to the first lesson, which are indicated in Table 1.

Table 1 shows many moments when trainees used their action plans and resources in order to contemplate the categories for an IIR.

In the first intervention, two of the five undergraduate students who formed the group of subjects in this research were present. Each of the five members is indicated by the letters *A*, *B*, *C*, *D*, and *E*, respectively. In it, the steps destined to be executed are 1 and 2, which according to the planning with the group of subjects refer, respectively: *cliché* of the studied situation and spontaneous panorama.

The first of these, however, deals with the initial moment of the methodology, where the teacher will present the proposed theme for the study and the problem about which they will have to discuss. Whereas in the second, as already mentioned in the previous chapter, students will select what is and what is not relevant to the study of

that problem.

Table 1 Moments of the First Lesson With IIR Methodology

Video Lesson Recorded	Category 1 Negotiation	Category 2 Content organization	Category 3 Discussion points manager	Category 4 Time manager	Category 5 Constant update
Recording of the first lesson	Recording's time 8min07s	Recording's time 10min07s	Recording's time 6min15s	Recording's time 11min37s	Recording's time 07min13s
IIR's steps (1 and 2)	***A*** negotiates the choice of the themes for the proposed notice.	***A*** organizes the content to be worked on and how it should be done.	***A*** and ***B*** read the notice for each grade.	A distributes functions and gives guidance for development time.	A recommends the groups some points to rethink what was decided.
Subjects: ***A*** and ***B***			Recording's time 9min07s	Recording's time 12min47s	
The total duration of the recording — 45 minutes			***A*** and ***B*** guide the formation of groups and points to discuss.	***A*** and ***B*** talk quietly among themselves, emphasizing which steps still need to be developed and that the first to be lanched was the Cliché.	
Cameras (1) and (2), frontal, and central in the room.			Recording's time 10min27s	Recording's time 14min02s	
			A and ***B*** organize the platforms.	***A*** and ***B*** speed up your explanations to end the first two steps and give guidance for the next classes.	

In addition, according to Table 1, there is a higher frequency of moments where the interns acted within the interdisciplinary expectation regarding those indicated by categories 1 and 3, that is, negotiation and manager of the discussion points. The first is due, in this context, to the fact that one of the stages that were proposed by the trainees to high school students needed a discussion on the topic of energy and generation.

At this point, the students — in the form of platforms with four members — discussed and organized their thoughts in order to put on the agenda what they understood about what had been asked of them. On the other hand, during the initial phase of the class corresponding to the moment [8min07s], it is noted that subject A was working in one of the groups in order to mediate the discussion, that is, helping them to reflect on the relevant and not relevant aspects to what was being discussed. In addition, there was an initial concern on the part of these interns when starting the implementation of the project, as they counted on the presence of the full professor of the class and this ended up interfering with the scheme of action used by the intern, as we can see in his report in the later stage implementation:

> "[…] We distributed the material and let the students continue with the activity. At that moment I felt that the teacher intervened in a negative way, since he was stimulating the students' responses or directing in some way. I was worried because I was constantly policing myself not to give an answer that directed the students. So, I had to intervene in the teacher's answers a few times." — Report of subject A.

Another essential point for this phase and, which can be discussed, was the concern of undergraduate's students A and B with the progress of the process as seen in the concentration of moments indicated in category 4 of Table 1, which did not happen in the second and third interventions.

This is due, however, to the fact that the five members none of them had ever participated or worked with this type of methodological approach, as reported during the initial and later stages of this research:

> "[...] It is that in the first place we had never worked with this methodology before and I had never worked with 4 teachers at the same time. Anyway, I didn't feel comfortable with this situation." — Report of subject B.

The insecurity factor also influenced during the application of the first intervention, because the lack of knowledge about the methodology and the work of teaching in a group were elements that weighed on the trainees throughout these interventions. Trainee D can only participate from the second intervention, but in his report in the step after the implementation of the IIR says:

> "[...] I felt insecure before starting the class, for two reasons, the first because I never had an activity that resembled this in all my years of study and only heard about the methodology by projects of some colleagues who have already worked in schools or had teachers who used this approach. The second reason was because of not being able to participate in the first day and getting on the "moving train". […]"- Report of subject D.

In this first intervention, it can be understood that a good part of the entire course of the class, the interns acted in an interdisciplinary way, that is, their action schemes included the essential categories for an interdisciplinary practice provided for in an IIR by Fourez (1992; 1994; 2001).

5. Conclusions

At first, we could observe the reproduction of cultural aspects arising from an approach that in our research perspective we define as traditional. To the latter, we attribute to every scheme and resource that the teacher uses, and that represents a tradition of educational customs already perpetrated in Brazil. In this regard, the group of subjects in this research acted in an interdisciplinary way only in the first of the three interventions.

In a second step, we found that even in the presentation of the teaching methodology by projects to the undergraduate students (IIR) there was little adherence, and only a single group containing five undergraduate students was interested in developing it in the classroom during their internships. This is supported by the reports highlighted above, about the lack of knowledge of this methodology, of the insecurity that it causes due to the fact that it represents a culture for innovative teaching, as opposed to the traditional one used here as a reflection parameter.

Finally, it should be noted that the didactic strategies that undergraduate physics students, subjects of this research that is characterized as a case study, used throughout the implementation of interdisciplinary projects, at the moments highlighted above, transpired the reproduction of cultural patterns related to a scheme traditional.

According to Sewell Jr. (2005), these patterns are transformed and, concomitantly, they are reproduced within a social structure. An important point to be taken into account is that the classroom, in this research, was interpreted as being a social structure in which the social patterns experienced by students in their lives are reproduced and transformed.

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