Chapter 8
A Reflection on Research-Based Alternatives of Physics Teaching on Educational Activity System

Cristiano Mattos

Abstract In this chapter, we present a general reflection on the place of research-based alternatives compared to traditional physics teaching to professional formation, seeking to establish a broader dialogue with the works presented in the previous texts of this part of the book. Our main purpose is to localize alternative teaching proposals in the education's activity chain, since higher education activity is part of a larger educational system that connects basic school to productive working life. We indeed bring more questions than real answers since school-society relation has been the object of research for a long time in several research fields. We assume a radical position, seeking to grasp the root of this matter, thinking critically about the concrete conditions of the research-based teaching approaches, highlighting some points and presenting a preliminary overview of what could be a common ground to think about the research in physical teaching in higher education.

8.1 Introduction

We all know that any well-based knowledge is crucial for solving real-life problems and then well-based researches in teaching methods are welcome to any level of education. Its validation reflects the sincere efforts of researchers to produce better teaching and learning. However, the core issue of all educational activity is clarifying its own objective, i.e. what do we intend to teach? How do we intend to teach? And why do we intend to teach? The objective reflects the complexity of the activity that includes the coordination of several minor objectives constituting a hierarchically complex of objectives. Therefore, local actions, e.g. the application of new teaching methods, have local objectives such as learning a concept, a procedure or an argument. However, a discipline is just one of the coordinated actions of a larger activity (e.g. undergraduate course) that have specific purposes that must be specifically and differently coordinated to educate a physicist, an engineer or a physician.

C. Mattos (✉)
Institute of Physics, University of São Paulo, São Paulo, Brazil
e-mail: mattos@if.usp.br

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The same rationale can be applied when we understand the need of coordination between the university and the institutions of work placement. The objectives of both institutions must be coordinated in order to be considered as a professional training unit. Here we identify the curriculum as a possible unit of analysis of education that allows identifying the internal coordination levels of an entire course, even those objectives society give financial support.

In this way, the meaning of research-based alternatives to traditional physics teaching emerges in the relations established within a complex educational activity chain that involves persons. In addition to the institutional coordination established, the meaning of a new method of teaching will depend on the theoretical and methodological foundations, the conceptions of human being, human relationship and scientific knowledge it is based on. All aspects related to the epistemological, ontological and axiological dimensions reflect the choices made by the proposers of the new method.

8.2 Higher Education Teaching Cha(lle)nge

Researches to support teaching methods are fundamental, mainly because considering education as human science could be seen in a pre-paradigmatic period, since there are a dozen of theoretical proposals to education or science education.

Nevertheless, a common ground on different physics education theoretical perspectives is that to teach physics, in any level, but particularly in higher education, a teacher must have a deep knowledge of physics. However, at the same time, we already know that this scientific proficiency is not enough to ensure students' learning or engagement. Besides mastering on scientific subjects, science or engineering or medical people should understand what meaning the scientific knowledge they master would have in the social environment they will work in.

At the same time, independently of which profession a student pursue, he will have to establish educational relationships that are intertwined in an educational process of convincing others about the validity of the knowledge he wants to use as a solution to the problems for which their expertise has been called to account. Then, in diverse life situations, such professionals could become teachers with different styles, such as authoritarian, permissive or authoritative, determining the types of relationships with their future colleagues or students (Chamundeswari 2013), which may facilitate their engagements in the productive processes for which they are called to participate in, whether at a school, university or industry.

8.3 Concrete Conditions to Sustain an Educational Change

Traditional physics teaching is usually based on the assumption that the successful teaching is the one where the physics content is reproduced specifically on problem-solving activities (Ceberio et al. 2008). Moreover, in higher education, particularly in physics courses, many ontological, epistemological and axiological assumptions about physics are crystalized. Very often teacher and students at physics courses, for instance, do not use to debate the nature of science or the role of history of science (Gooday et al. 2008; Höttecke and Silva 2011) to understand the pragmatic achievements of science. This approach usually emerges in cultures where the scientific knowledge is considered True (with capital T).

This kind of epistemological and ontological commitments reflects students' and teachers' alienation from a broader complex relation the scientific knowledge has with social and cultural human life. In general, this view of science leads teaching to a banking education or a teacher-centred education method, where the value and ends of knowledge to be taught and learned seem to be not just predefined but also crystalized.

Therefore, in order to implement higher education alternative teaching methods, the proposers must face not only the resistance of students and colleagues but also the resistance of institutionalized traditional teaching cultures (e.g. Hernandez et al. 2014). Such institutionalization could be found in different levels of the educational activity, educational boards, committees and "unifying educational programs", which reproduce the epistemological idea that physics science is one and well defined, the ontological idea that the nature exists independently of the humankind and the axiological idea that the value of scientific knowledge is major for human well-being. Unfortunately, there is no room here for a deeper discussion regarding these assumptions. In spite of these ideas being widespread, we barely have an institutional space to discuss such commitments that lead to "ways-of-being scientific".

One of the consequences of those commitments is that facing institutional and personal resistance to understand that science education belongs to the field of human sciences; many teaching experiments were lost seeking for "hard science" recognition, trying to be validated as a physical experiment (Schultz 2001; Handelsman et al. 2004). Beyond that, several institutions have highly bureaucratic steps to implement new syllabus or curricula allowing pavement to new teaching methods.

8.4 Generality of the Research

We assume that new teaching methods would be an answer for educational demands. However, one of the biggest problems to generalize human science methods, particularly in education, is to know if the demands are the same in different communities or countries, with different culture and social needs. This assumption put in check the idea that the content or the teaching method should be the same in all contexts.

Considering specific teaching methods as special cases of a more general method, we have to establish what "general" means. Is it a method applicable to any sociocultural context, regardless of any concrete conditions for implementation? Is it a students' and teachers' proof method? Or should they be methods with social contexts domains of validity, where each domain is different considering different commitments (Burchianti and Barrero 2016)? Such commitments or principles refer to the nature of the scientific knowledge, the "methods" used to produce the knowledge and the values and ends we attribute to this knowledge. In an interdisciplinary research area such as science education, one of our biggest challenges is to clarify what commitments we are assuming, allowing others to understand what are the principles our educational innovations are based.

The previous texts in this chapter presented research-based alternatives to traditional physics teaching. Their objects are the physics teaching in higher education for engineering courses, teacher formation, bioscience areas and teaching to novice and almost undergraduate students. They are using different concepts, such as metacognition, intuition, cognitive scaffolding and different interactive methods such as student working groups, individual strategies, etc.

All researches are well based and have determined the context of validity of its results. However, for instance, no one has asked what is the role of students' professional choice in learning or what is the meaning or the value students give to science. Those points are usually default and well stated. It seems reasonable to think that these points can determine different engagements with knowledge in the discipline, in the whole course, or can determine the will for a productive engagement in all education activities.

For example, generally we could agree that teaching children in an oncological hospital class, or teaching people without material support, or teaching those who don't want to learn, or even teaching in war situation, demands quite different ways to teach (Mattos and Tavares 2014; Wattar 2014; Nathan 2006; Johnson 1944). Far beyond, all those situations demand clearly understanding of what purpose these persons have with the knowledge they are willing to learn, meaning that teachers should have an ethical agency to grasp the axiological dimension of learners' intentions.

According to our observations about Brazilian preservice physics teacher's profile, we know that most of them accept to be a teacher only late in their training course. On the other hand, engineering students often realize, after their undergraduation, that the profession they were in is not the one they would like to work (Fiske 1996). However, most of our teaching methods take as granted that students' career choice is definitive in the beginning of their university studies.

Of course, it is possible to identify many students productively engaged, but most of them have illusions about their careers and about how they will experience the use of the specific contents throughout their lives (Wyer 2003; Tan-Wilson and Stamp 2015). Nevertheless, alternative student-centred methods are needed to take place of those teacher-centred that are fading away students' illusions about their careers, giving hopeless perspective to profession as a joyful life.

8.5 Curriculum

In the last years, for different reasons, efforts to unify curricula in Europe, the United States and Brazil have been made, most of them trying to build a more global curriculum from basic school to the university levels. However, we are facing contradictions based on the dualism between local and global forces disputing space on curricular objectives and contents (Vulliamy 2010; Wattar 2014).

Curricular transformation is a necessity when we understand that societies are transforming and new demands emerge from different economic and social fields (Carnoy 1999; Haste 2010). At the same time, in many physics education institutions, curricula are untouched. One of the main evidences of contents' immobility in physics teaching practice is the stability of textbook contents. There are assumptions about the nature of taught knowledge unchanged in the best sellers' textbooks used all over the world, such as "Halliday", "Tippler", "Goldstein" and "Callen" among others. These textbooks present the same set of specific content with minor differences, structuring a worldwide standard physics list of contents (use to be called as curriculum). The problem is that the teaching method subsumed in these textbooks usually reinforces traditional teachers' understanding that there is only one way to teach the contents, which is the way they had learned physics.

Fortunately, contrary to these beliefs, the researches previously presented on this chapter introduced a diversity of methods. Michellini and Stefanel pointed out the central ideas that Peru Group is trying to achieve, interpreted by Guisasola (cross-reference) as the need for:

> turning the ways in which physics is approached, changing the role of each topical areas, individuating specific application of physics in the professional filed of the degree, and offer instruments and methods building the different fields.

The excerpt indicates the assumption that physics must be taught not only by different methods but also for different physics training needs or different educational objectives.

Despite the local advances made in the previous work of my colleagues, we can say that we are in a pre-paradigmatic moment where innovations dispute a place in the sun, trying to be viewed as more successful than others are. The result in the last years is the proliferation of a soup of letters that are popping up all over the world as acronyms, for instance, SCALE-UP (Student-Centered Activity Learning Environment with Upside-Down Pedagogies—Beichner et al. 2007), PI (Peer Instruction—Crouch et al., 2007), PUM (Physics Union Mathematics), REACT (Relating, Experiencing, Applying, Cooperating, Transferring—Crawford 2001), JiTT (Just-in-Time Teaching—Novak et al. 1999) and Isle (Investigative Science Learning Environment—Etkina and Van Heuvelen 2007), among others.

8.6 Evaluation

Thus, it is imperative to advance in developing evaluation criteria to create a common ground criteria should be created, not as a way to force a unified teaching method or curriculum such those the multinational educational corporations would like to establish all over the world, treating educational problems with the same logic of economic problems.

These assessments should be carried out throughout various hierarchical levels of the education system from the immediate learning concept with local problems presented in classroom situation to long-term evaluations throughout all undergraduation courses and beyond school walls reaching in the wild.

It is important that the evaluation overcomes the school walls reaching people's life, but it is paramount to evaluate our capacity to live together, as a social being, dimensioning the role of the scientific knowledge to construct a compassionate life to the humankind. It is essential to overcome dehumanization structures of power that treat each individual as an expendable unity of a depersonalized whole.

Considering the social system as a complex one, each hierarchical level brings different epistemological, ontological and axiological commitments. To overcome students' simple engagement, a productive engagement should be aimed at different hierarchical levels, in a way that students do not only consume knowledge but also produce knowledge collectively. This tension between consumption and production of knowledge leads us to question what problems are we offering to our students? Are these problems engageable? Schools' mission should be to introduce and highlight the social contradictions and to overcome dichotomies such as school's indoor versus outdoor problems, individual versus collective problems, personal versus political problems and local versus global problems.

In order to overcome these dichotomies, students should create meaningful relationships between the immediate specific content and curriculum objectives, allowing then to connect an immediate learned concept with the conceptual ecology required to understand its role in the construction of alternative social concrete conditions for a democratic and respectful society.

8.7 Conclusion

Coherently with our initial proposition, we are bringing more questions than solutions. We do not work with the idea of a general method. From the perspective of dialectical materialism, a method is an "epistemology within an ontology"; in other words, the objects emerge within the means we know it (Rodrigues et al. 2014). Then, beyond the generality of science, science educational methods should take into account local demands and its relation with global ones. Furthermore, the science education methods and their associated evaluation criteria should consider learning as a lifelong learning (Longworth 2003).

The problem of how could people educate others through all their lives had driven us to consider education in a broader sense, where a critical learning society accomplishes education in all hierarchical levels of the social system (Welton 2005; Arlow 1999; Sundström and Fernández 2013; Wells 2010). Then, facing social problems, teaching responsibilities should came not just with the individual teachers' practice but also with an institutional structure to support the needed institutional changes to implement sustainable research-based teaching activities.

The reflection we made led us to more questions: when we think education as a complex hierarchical system encompassing classrooms, schools, societies, nations and cultures, what should be "conserved and transformed" in physics teaching activities? Should teachers and engenieers learn the same physics using the same methods? What are the collective learning difficulties? What is the nature of the learning difficulty: cognitive, social, historical or cultural? Can the difficulty be attributed to the teacher-students relationship, such as different power relations? When are teacher and student co-responsible for the teaching-learning process? What are the responsibilities of the university in the civilizational process? (Arthur and Bohlin 2005).

Mila Kryjevskaia (cross-reference) wrote, "it is a common expectation that, after instruction, students will consciously and systematically construct chains of reasoning that start from established scientific principles and lead to well-justified problems". Escalating the expectations, we hope that these chains of reasoning should go further in the higher levels of the hierarchical chain of problems that connect students' immediate life to broader social-historical-political problems, reinforcing commitments and complexifying the consciousness of their role in the humanization process.

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