# Nicolò Defenu – Teaching Experience

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## Introduction

*"Outstanding researchers are not always the best teachers."*

This sentence has been the "mantra" of several discussions between my colleagues and myself during my undergraduate and graduate studies at La Sapienza University in Rome. At the time, we experienced several courses with outstanding internationally recognised researchers, but it appeared to us that, while a prestigious lecturer may rise the enthusiasm of the audience, in most of the cases the best learning experience were conveyed by young researchers, who concentrate on the development of an original teaching method. Such understanding has deeply shaped my academic experience, proving me the importance to develop a personal and effective teaching philosophy.
Too often teaching and research are seen as two separated, and even contrasting, aspects of the academic experience. On the contrary, they present two sides of the same goal, i.e. to extend the comprehension of the natural world around us. In fact, teaching is a vital part of any scientific career, as it provides the researcher with the necessary condition to spread his/her vision and to shape a proper legacy within the community. It is very common that researchers with the same course of studies have corresponding perspectives on the physics foundations as well as a similar vision for the future of science. When teaching, any successful researcher has to consider that the success of a research line passes through the formation of a school of thought, capable to prosecute and extend his/her own vision, beyond the span of a lifetime.
Conscious of these concepts, I have closely observed the lecturers during my last year of undergraduate studies as well as during my entire PhD studies and analysed their teaching methodology in order to develop one of my own. This effort has been continued during my post-doc experience both at the University of Heidelberg and at ETH Zürich, where I had the opportunity to teach as a tutor and to supervise master students, as listed in the section below. The two key considerations I have derived from my experience are the following:

- Understanding may come by diverse point of views and perspectives, so the lecturer shall not be clouded by his/her perspective on a certain subject, but always try to convey the message from as many angles as possible.
- It is necessary to diversify the teaching methodology depending not only on the audience, but on the matter of the lectures. Especially, one shall modify the teaching approach between fundamental and specialised topics.

These two statements constitute the foundations of my teaching philosophy and have been proven useful along my entire teaching experience, as detailed in the following.

## Teaching Experience

During the employment at Heidelberg University, I have been deeply involved in the teaching activity both by tutoring graduate courses and supervising master thesis. The crucial aspect of my research experience at the university of Heidelberg has been the diversity of the taught courses, as seen in the following list:

- **Teaching Assistant for Advanced Condensed Matter Theory** **Feb.-Jul. 2017**
  *Heidelberg University, Instructor Prof. Maurits Havenkort*

- **Teaching Assistant for Condensed Matter Theory** **Oct. 2017- Feb. 2019**
  *Heidelberg University, Instructor Prof. Maurits Havenkort*

- **Teaching Assistant for Seminar on Statistical Physics** **Feb. - Jul. 2018**
  *Heidelberg University, Instructor Prof. Andreas Mielke*

- **Teaching Assistant for Theoretical Statistical Physics** **Oct. 2018 - Feb. 2019**
  *Heidelberg University, Instructor Prof. Bjoern Malte Schaefer*

- **Teaching Assistant for Seminar on Nonlinear Systems** **Mar. - Jul. 2019**
  *Heidelberg University, Instructor Prof. Andreas Mielke*

- **Head Teaching Assistant (Oberassistent) for Theoretical Statistical Physics** **Oct. 2019- Oct. 2020**
  *Heidelberg University, Instructor Prof. Luca Amendola*

My experience in teaching advanced courses as *Advanced Condensed Matter* and *Nonlinear Systems* has profoundly shaped my subsequent work as a tutor in more fundamental topics. Indeed, I noticed that several students had difficulties applying the propedeutic concepts from quantum mechanics and thermodynamics to more advanced subjects. A paradigmatic example of this fact has occurred during one of my first tutor classes on *Advanced Condensed Matter*, while discussing the application of perturbation theory to quantum mechanical problems. The lecture was following the cooperative learning approach and it was focused on the application of perturbation theory to the quantum harmonic oscillator in a box potential. The initial discussion concerned the theory of the quantum harmonic oscillator, which should have been familiar to the students from their bachelor studies. Indeed, most of them could remember the spectrum of the harmonic oscillator as well as its eigenfunctions; however, nobody was able to discuss the consequence of the spectrum discreteness on the physics of the model nor the relation between such discreteness and the boundedness of the potential. Such experience shaped my teaching philosophy in fundamental courses, where I always underline the connections between different subjects and show the students how any peculiar topic can be inserted in the bigger framework of the knowledge necessary to pursue actual research courses.
During my present employment at ETH Zurich, my teaching experience has further developed participating as a tutor to proseminar courses both at master and bachelor level:

- **Teaching Assistant for the master proseminar on Renormalization Group** **Oct.-Dec. 2020**
  *ETH Zurich, main Instructor Dr. Ramasubramanian Citra*

- **Teaching Assistant for the bachelor proseminar on Field theory and Classical physics** **Jan. 2021-Ongoing**
  *ETH Zurich, main Instructor Prof. Gian Michele Graf*

My experience in teaching advanced courses is not limited to Heidelberg University and ETH Zurich, but also comprehends several guest courses and lectures, which I have given in internationally recognised institutions such as SISSA, UMASS (Boston) and IIP (Natal), as seen in the following list:

- **Main instructor of Mini-Course on Functional Renormalization Group** **Nov. 2017**
  *IIP (Natal), Main Instructor*

- **Guest Lecturer on Functional Renormalization Group** **Apr. 2019**
  *Umass (Boston), Main Instructor Dr. Francesco Caravelli*

- **Main Instructor for Functional Renormalization Group** **Jun. 2019**
  *SISSA (Trieste), Co-Instructor Dr. Andrea Trombettoni*

- **Main Instructor for Functional Renormalization Group** **Apr. 2020**
  *SISSA (Trieste), Co-Instructor Dr. Andrea Trombettoni*

The last experience as a lecturer at SISSA has been particularly challenging due to the present world pandemic, which has forced all lectures to be held in online mode. A consistent part of my lectures on functional RG were constituted by a practical part, where the students learn how to solve functional differential equations using

different numerical techniques. The discussion of such numerical tools always raises several questions regarding the technical details of the calculation, which are not easily answered remotely. Nevertheless, online teaching also presents several benefits as the possibility to share and discuss references as well as the possibility for the students to contribute to the lectures in a more casual and parithetic environment. Such positive aspects have been particularly evident in my experience as a master thesis co-advisor with two students in the last year:

- **Master thesis co-advisor** **Dec. 2020**

  *Title: "Dynamical Quantum Phase Transitions in the Spherical Model"*
  *Candidate: Marvin Syed*
  *Main Advisor: Dr. Tilman Enss*

- **Master thesis co-advisor** **Oct. 2020**

  *Title: "Renomalization group approach to the calculation of integrals"*
  *Candidate: Alberto Catalano*
  *Main Advisor: Dr. Andrea Trombettoni*

- **Master thesis co-advisor** **Ongoing**

  *Title: "Lattice effects within Functional RG: the $d = 2$ XY model"*
  *Candidate: Pascal Schweizer*
  *Main Advisor: Prof. Dr. Gian Michele Graf*

- **Master thesis co-advisor** **Ongoing**

  *Title: "A functional RG approach to PT-symmetric models"*
  *Candidate: Benjamin Liégeois*
  *Main Advisor: Prof. Dr. Gian Michele Graf*

## Teaching Philosophy

The first aim of any fundamental physics lecture should be the construction of a proper analytic mindset and the improvement of the mathematical tools necessary to comprehend any phenomenon which may be encountered in the future. Such goal can be achieved only by the development of a personal point of view on the ground topics in physics; thus my lectures always focus not only on the interaction between myself and the students but also between the students themselves. Therefore, cooperative learning is employed to tackle such parts of the syllabus not in need of tight supervision. The most beneficial effects is the incentive toward the creation of packs of motivated "research groups" able to lift the sense of isolation that often is met during STEM field studies and empowering the different people participating.
Moreover, I constantly stimulate the students to understand the physical consequence of any mathematical formula. Especially, for basic courses I concentrate on such mathematical derivations, where the physical meaning of the various passages may be comprehended. Usually, I do not directly discuss more involved mathematical derivations during frontal lectures as I prefer to focus on the mathematical hypothesis and thesis of any derivation, since they contain the most relevant physical information. Longer and more involved mathematical calculations are given to the students as home exercises or as practical exercises during the lecture itself. Then, the doubts and difficulties encountered by the students will be the starting point to deepen the analysis of the mathematical derivation and only finally, in the most complicated cases, the derivation will be displayed completely during a frontal lecture.
When discussing advanced subjects I noticed the tendency of the students to memorise concepts and jargon without connecting them with the notions they already posses nor with the fundamental physics questions. Therefore, during advanced lectures I continuously switch perspective, trading "saddle point approximation" with "mean-field theory" and so on; in such a way to stimulate the students to build connections between the notions under study and the ones they already possess from other courses.
For smaller classes and thesis supervision it is important to comprehend the background of each student knowing the lectures and courses they already attended as well as having a clear idea of the ground formation they posses. Indeed, each point of view on a subject is the result of a personal history and needs to be properly

understood in order to advice references and discuss the topics in a comprehensible language. For this reason I continuously ask the students about their perspective on each subject inciting them to trust their intuition. In the future, I plan to develop my “cooperative learning” method even more adopting the “flipped classroom” approach, in which the lecture time in the classroom is used to explore topics in greater depth and create meaningful learning opportunities while students are initially introduced to new topics outside of the classroom. Therefore, I am going to employ video lessons, collaborative group discussions and digital research in order for the students to develop insight on each topic, while the classroom time will be devoted mostly to collective discussions, where the students have the possibility to express their vision on each problem and compare it with the one of others, under the guidance of the lecturer. Such teaching method shall possibly be favoured by the present online lectures format, which may be partially maintained in the future.