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Investigating physics teaching and learning in a university setting

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Summary. — Most of the initiatives taken by the European Community and by other countries internationally in the field of science education focus on elementary and secondary levels of education, and relatively few reports have analysed the state of science education in higher education. However, research in science education, and in particular in physics education, has shown repeatedly that the way teachers teach in elementary and secondary school is strongly influenced by their own prior experience as university students. The education that future professionals, such as scientists, engineers and science teachers, receive at the university is worthy of study, because it allows us to investigate student learning relatively independently of developmental issues, and because of the more rigorous treatment of physics topics at the university level. For these reasons, it seems appropriate to identify, analyse and provide solutions to the problems of teaching and learning related to the university physics curriculum. In this symposium, we present examples of physics education research from different countries that is focused on physics topics

1. – Introduction

The Physics Education Research community consists of physicists who apply the same logical rigor and standards of evidence to education topics as researchers in other areas of Physics do to their subdisciplines. Research on Physics Education is not only concerned with innovation in teaching but also with the analysis of the process of teaching and learning based on empirical evidence. In the 1980s, the first research papers dealing with Physics Education Research (PER) were published in the American Journal of Physics.

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In the 1990s, the European Journal of Physics also started to publish studies on PER. In 2005, the international community of researchers in physics education established its identity as a distinct research community with the creation of a new journal, Physical Review Special Topics-Physics Education Research (PRST-PER), recently renamed Physical Review - Physics Education Research (PR-PER). Finally, in 2013, GIREP decided to support the field of physics education research at the University level by proposing the GIREP Thematic Group PERU (Physics Education Research at University Level). This symposium is the first outcome of this GIREP initiative.

Research in Physics Education at the University level has been focused mostly on introductory/entry-level physics courses. (Recently, research interest in upper-level courses has been increasing rapidly, as described by Paul van Kampen later in this paper.) Areas of active investigation in Physics Education Research at the University level are diverse, and include investigations into 1) specific topical difficulties within physics; 2) student learning of problem solving; 3) student epistemologies and their effect on learning; 4) student use of mathematics in physics; 5) student learning of laboratory practices and of reasoning from evidence; and 6) the development of identity as scientists during university education. Just as a physics investigation in materials science has practical technological outcomes, investigations into student learning often result in research-based curricular materials, and many Physics Education researchers also work on curricular development and on measuring the effectiveness of curricular modifications. Examples of these investigations into student learning and of instructional materials developed on the basis of this research include Hsu *et al.* (2004), Guisasola *et al.* (2010), Hieggelke *et al.* (2013), and Etkina and Ruibal-Villasenor (2008).

This paper aims to describe and discuss some examples of studies on teaching and learning of specific topics at university level. In particular, two of the contributions deal with students' conceptual knowledge in topics of electromagnetism and modern physics, while a third study looks at students' struggles with deriving meaning from physics equations.

2. – Research focus on topic-oriented demands

2˙1. *Students' preparation for using mathematics in introductory physics*. – The study presented by Stephen Kanim describes an investigation into *students' preparation for using mathematics in introductory physics*. In typical introductory courses, proportional relationships are ubiquitous, starting with definitions of velocity and acceleration in one dimension in the first few weeks of the course. Since students in introductory physics have had extensive instruction and practice in the use of proportions and of simple algebraic expressions over many years, it is reasonable for instructors to assume that proportional reasoning should not be a source of difficulty. However, this is not the case: While students may be able to perform *procedures* involving ratio and proportion successfully, the research conducted by Stephen Kanim at New Mexico State University, Suzanne Brahmia at Rutgers University, and Andrew Boudreaux at Western Washington University shows that a large fraction of these students cannot reason about these procedures in the ways expected of them in physics.

As part of this study we have identified six components of proportional reasoning that we think are required for fluent use and interpretation of ratio quantities in physics. These components are provisional, and are based on physics education and mathematics education research results that describe students' difficulties with mathematics in physics; on interviews that we have conducted with students about physical situations requiring proportional reasoning; and on our judgment about the types of reasoning that we would like our students to be able to do about proportions (both in physics and in general). They are 1) recognizing ratio as an appropriate measure; 2) verbal interpretation of a ratio; 3) construction of a ratio to characterize a physical system or phenomenon; 4) applying a ratio to make quantitative predictions about novel situations; 5) translating between different representations of direct proportions; and 6) reasoning about situations where relationships are not direct proportions.

For each of these six components, we have developed a set of questions in multiple contexts intended to probe student fluency. Initial versions of these questions were free-response, and after analysis of student responses we developed multiple-choice versions. Here we illustrate the type of question for a few of the components, as well as data from administration of these questions as pre- and post-tests in large classes.

As described in Simon and Blume (1994), many people inappropriately use differences when ratios are more relevant, or fail to recognize that a given ratio quantity is actually a measure of something rather than an assigned index. One example of questions we have asked that probes whether students use proportion when appropriate is the building "squareness" question:

You are riding in an airplane. Below you see three rectangular buildings with the rooftop dimensions:

Building A: 77 ft by 93 ft,
Building B: 51 ft by 64 ft,
Building C: 96 ft by 150 ft.

You are interested in how close the shapes of the rooftops of the buildings are to being square. You decide to rank them by "squareness," from *most* square to *least* square. Which of the following choices is the best ranking?
a) A, B, C, b) B, A, C, c) C, A, B, d) C, B, A, e) B, C, A.

Students who decide based on the ratio of lengths of the sides will choose a); students who decide based on the difference in lengths will choose b). When we asked this as a pretest question, only 21% of 770 students in an introductory calculus-based course intended for engineering majors chose a), while 70% chose b). At the end of one semester of physics instruction, results did not change, with 19% choosing a).

Given two related and varying quantities in a physical system, a ratio can often be formed from these quantities that is invariant. For example, the mass and volume of different quantities of a liquid can be combined to form an invariant density. We would like our students to be able to construct the appropriate ratio of these two varying quantities: Most often the error made is to construct the reciprocal. One question we have asked to diagnose this skill is shown:

A block suspended by a spring is made to bob up and down. The motion repeats itself over and over. You find that B bobs occur in 10 seconds. To figure out the number of seconds required for a single bob, you should:
a) divide B by 10, b) divide 10 by B, c) multiply B by 10,
d) none of the above.

Of 533 students, 37% correctly answered that the number of seconds required is $10/B$, with 60% constructing the reciprocal $B/10$. One skill that physicists often use to check whether they have constructed an appropriate ratio is to check the units: This is not a skill that many of our students have developed.

We have asked a variety of questions that focus on non-procedural aspects of proportional reasoning similar to the ones above across all six proportional reasoning components. Some generalizations emerge: 1) Student performance with individual components is highly context-dependent, with students exhibiting much better performance in familiar contexts than in unfamiliar ones. For example, when asked to compare densities of blocks of different sizes made up of identical material, about 85% can answer correctly; when asked an isomorphic question about charge density the success rate drops to about 55%. 2) Students are less successful answering questions with variables than without, with success rates on individual questions dropping 10%–20% when a number is replaced with a variable. These results are consistent with results reported by Torigoe and Gladding (2010) when they compared questions asked with variables and questions asked with numbers. 3) Densities and ratios involving time are ubiquitous in physics, yet they seem to be particularly difficult for students.

The general sense that has emerged from this study is of the fragility of students' mathematical knowledge — even for students in engineering and science majors at relatively selective universities. Many students have learned mathematics as a set of procedures, with little time and focus given to conceptualization of mathematical notions and processes. These students struggle with application and interpretation of proportional reasoning to physical quantities. In a standard introductory physics course, students are introduced to new quantities in unfamiliar contexts. Often these quantities are defined as ratios: Density, velocity, acceleration, spring constant, coefficient of friction, impulse, electric field, electric potential, capacitance, heat capacity, frequency, are only a few. As instructors, we expect that —since they have seen ratios and proportions for many years in their mathematics classes —these definitions will be straightforward. However, our results indicate that while students may do well on questions posed in a familiar way, with familiar contexts, and with numbers, performance drops when variables are used, when the context is less familiar, or when they are asked to reason about proportions in ways they have not experienced. As a result, it is easy for students to become overwhelmed by the ways that mathematics is used in physics.

Moreover, exposure to a semester of physics apparently does little to strengthen this understanding or to develop fluency with use of proportions. By and large, results for the questions we have asked are about the same after a semester of using ratios and proportions in physics courses as they were at the beginning of the semester. If we are to improve student fluency with mathematical reasoning in physical contexts (and we believe that this should be a major goal of an introductory physics course) then we need to better understand how students think about mathematics, and we need to develop curricular materials that explicitly address students' mathematical difficulties in the context of physics.

2˙2. *University students' difficulties with the role of experimental set-up in the process of spectra formation.* – The research presented by Lana Ivanjek focuses on *University students' difficulties with the role of experimental set-up in the process of spectra formation.* The structure and formation of spectra are a part of university and secondary school curricula both in Croatia and in the United States. Systematic investigation of students' understanding of atomic spectra was conducted among 1000 science majors in introductory physics courses at the University of Zagreb, Croatia (L. Ivanjek and M. Planinić) and the University of Washington, USA (P. Shaffer and L. McDermott). The research had two aims: 1) to explore the extent to which university students are able to relate the wavelength of spectral lines to the transitions of electrons between energy levels in an atom, and 2) to explore the extent to which students recognize the conditions under which discrete line spectra are formed (or not).

In the first part of the study (Ivanjek *et al.*, 2014) we have investigated university student difficulties with energy levels and transitions. During that investigation, it became clear that many students had an incomplete or incorrect understanding of how energy levels and transitions of electrons between them are related to discrete line spectra. When asked about the connection between energy levels and spectral lines, many students did not seem to recognize that each spectral line is a result of a transition of an electron between two energy levels. There was a strong tendency to associate each spectral line with one energy level. Even students who recognized that each spectral line involves two different energy levels often did not have a correct model for the emission of light. We designed the tutorial, *Atomic spectra,* to help address the most common difficulties that we identified in the research. The tutorial guides students through an inductive process of finding the relationship between the energy levels in an atom and the spectral lines that are observed. In the process, the tutorial explicitly addresses specific difficulties, in particular, the tendency to treat spectral lines as if they had a 1-to-1 correspondence with the energy levels. The assessment of the tutorial indicates that the instructional strategy used in the tutorial can be effective for many students. The post-tests probe student ability to apply concepts and reasoning to situations that differ from those in the tutorial and that require a more complicated chain of reasoning to answer. Comparisons with results from simpler pretest questions indicate that the tutorial has helped many students significantly improve their understanding of atomic transitions.

The focus of the second part of the study is student understanding of the role of the experimental setup in formation of a line spectrum. In the first stage, semi-structured demonstration interviews were conducted. Based on the insights from the interviews, two questions that probed that aspect of student understanding were constructed and administered to students. The data were obtained from students at the University of Zagreb and at the University of Washington. The students at the University of Zagreb included two populations: second-year physics majors in an introductory calculus-based physics course ($N = 50$) and junior physics majors ($N = 98$). The second-year students had completed calculus, General Physics 1–3 (mechanics, electromagnetism, waves, and optics) during their first year and were enrolled in General Physics 4, which covers thermal and modern physics. The juniors had completed a course on quantum mechanics. Most of the UW students ($N = 660$) were in the standard introductory calculus-based course (UW Intro). The others ($N = 85$) were in an “honors” section (UW Honors). All had completed mechanics, electromagnetism, waves, optics, and were beginning to study modern physics. Instruction was supplemented by weekly tutorials.

Already during the interviews with the nine junior physics majors at the University of Zagreb it was noticed that they struggle with the role of different parts of experimental setup. The results from written questions demonstrate that difficulties are widespread. In the written questions that were given after the lectures on the spectroscopy, only between 20% and 30% of the students recognized that the type of the light source is critical for the formation of a line spectrum. Students were often treating a prism as if it always yielded a continuous spectrum, treating spectral lines as if they were always visible, and most of them were confusing discrete line spectra with diffraction patterns. In their explanations, many student answers suggested a belief that light passing through a prism yields a continuous spectrum no matter what the light source. Students also incorrectly stated that narrowing the slit through which the light passes before reaching the prism and replacing the prism by a diffraction grating would make a continuous spectrum become discrete. They did not seem to be distinguishing between discrete spectra and diffraction patterns. The following answers from students in the introductory physics course demonstrate this difficulty:

"*The grating would make the light that passes it discontinuous so the spectrum on the screen will become discrete*".

"Narrowing the slit would create a wider beam so it would spread out the image on the screen creating a discrete pattern".

Results from our investigation of student understanding of spectra have been used to develop instructional materials for introductory physics courses. The materials were designed to address student difficulties with basic spectroscopic experiments. Three different instructional materials were developed: tutorial, tutorial homework and an online spectra application for homework. All of the materials guide students through different experiments with different light sources, slits, prisms, and optical gratings. Students predict what they would observe on the screen in different experimental set-ups. The main goal of these materials is to help students to distinguish between a diffraction pattern and a discrete spectrum and to recognize the role of the different parts of the experimental set-up in the formation of a spectrum. The results from the post-tests demonstrate a need for improved instructional materials. There is also a need to create laboratory-based, instructional materials on spectroscopy for prospective and practicing precollege teachers with a focus on how the spectra are formed.

The specific difficulties described are symptomatic of more general problems. The errors made by the students indicate that many failed to recognize that discrete emission spectra are associated with light composed of only a finite number of wavelengths. Even though discrete spectra are typically introduced to help motivate the idea of energy levels and transitions of electrons between them, only few students seemed to understand the connection.

Many students thought that continuous and discrete emission spectra can be transformed one-into-the-other by making changes to the optical instruments that are used to observe them. The responses suggested a wide variety of difficulties associated with the optical instruments themselves. At a more general level, however, they indicated a failure of students to understand that a discrete spectrum is associated with light that has a finite set of wavelengths.

2˙3. *Characterizing university students' use of the electromotive force concept in electromagnetism.* – The aim of the study presented by Kristina Zuza was to investigate and analyse the difficulties that students in the first years of university encounter when they try to comprehend the concept of electromotive force (emf) in contexts in which it is generated by electromagnetic induction (EMI). This study is a follow-up to previous research by Garzon *et al.* (2014), which looks at the problems faced by university students in trying to grasp the concept of emf in the context of transitory currents in resistive direct-current circuits. The research is a collaborative study among the University of the Basque Country (K. Zuza and J. Guisasola), the University of Leuven (L. Bollen and M. De Cock) and Dublin City University (P. van Kampen).

In a previous study (Garzon *et al.*, 2014), we discussed the importance of students learning the difference between emf and potential difference. Most teachers in mechanics differentiate clearly between work and energy, but in the teaching of concepts like emf (work per unit charge) and potential difference (potential energy per unit charge) an explicit distinction is not always made. It is this lack of conceptual differentiation that can often lead to confusion among students. Moreover, in a context in which electromagnetic induction (EMI) is caused by a magnetic field that is changing with time or by the movement of a conductor in a magnetic field, the work done in moving the charges is carried out by "non-conservative" forces, and so the concept of potential difference cannot be defined whenever the circuit in which the induction is produced is a closed one. Potential differences in induction phenomena can only be defined in open circuits in which terminals the charges are grouped together and a Coulombic electric field is generated.

This study sets out to investigate students' comprehension of emf generated in electromagnetic induction phenomena. In particular, we wish to answer the following research questions: i) What is the students' understanding of the concept of emf after instruction in electromagnetic induction? ii) Do students distinguish between emf and potential difference concepts in induced current circuits?

To find out what undergraduate students have understood about the concept of emf in electromagnetism, engineering and physics students from Spain, Belgium and Ireland were given a questionnaire after they had studied the subject in class. The research was carried out at the University of the Basque Country (UPV/EHU, 89 students), at the University of Leuven (KUL, 100 students) and at Dublin City University (DCU, 30 students) over the last two years. All first-year students had at least completed one or two years of physics at high school and they received a semester of teaching on introductory electromagnetism. The electromagnetic induction chapter is taught for 4 to 8 lecture hours of this course. Lectures were given by experienced teachers in the Physics Department.

Our methodology consisted of identifying categories and accounting for them, following the theory of phenomenography, which shows how different ways of perceiving and understanding reality (that is to say, concepts and associated ways of reasoning) can be considered as categories of the description of reality (Marton, 1981).

In this brief description of the research, responses to one question are discussed. The question was designed to investigate students' ideas about emf in circuits in which the electric current is generated by electromagnetic induction. This question was included in a broader questionnaire, which is not the focus of this study. The question presents a conducting coil with a surface area S of $0.012\,\mathrm{m}^2$ and a resistance of 5 Ω positioned between the poles of an electromagnet that produces a uniformly changing magnetic field for which $\mathrm{d}B/\mathrm{d}t = 0.025\,\mathrm{tesla/s}$. This is a situation that is familiar to students in academic contexts and is studied in many textbooks for introductory physics courses. The students were first asked whether or not a potential difference is induced. Students have to explain their answer. Secondly, students were asked whether or not a current I is induced. If so, students have to explain how they would calculate it. The students have to calculate the EMF induced. To do this they must apply Faraday-Lenz's Law ($\varepsilon = -\mathrm{d}\Phi/\mathrm{d}t$) taking into account that as there is no variation in area, but that the flux variation will be due entirely to the temporal variation in the magnetic field ($\mathrm{d}\Phi/\mathrm{d}t = S\mathrm{d}B/\mathrm{d}t$).

The results obtained are shown in table I. Although the students' curriculum in the three universities is similar, it is not the aim of this study to make comparisons or rankings. What this study seeks to identify are the students' main thinking patterns when interpreting the concepts of EMF and potential difference and to see whether or not there are similarities in the responses collected in the different countries.

This is ongoing research and so we only outline preliminary results here. As can be seen in table I, even after classroom instruction, only a minority (less than 10% of the students) had a sufficient comprehension of electromotive force in the context of EMI. Incomplete or incorrect reasonings were identified that were common among

Table I. – *The results obtained in each of the universities as percentages and the categories to which the various types of response were assigned.*

Category of description	UPV/EHU		KUL		DCU	
	a	b	a	b	a	b
A. Correct understanding of emf in electromagnetic induction context	0	2	0	28	10	0
B. No explicit distinction between emf and pd but ideas from the scientific model are used	7	25	5	22	10	17
C. emf and pd are mixed up	17	6	40	13	17	3
D. incorrect application of formulae/laws	27	30	18	12	27	23
E. no answers/no sense	51	36	37	25	36	57

students from all three countries. About one third of the students interpreted EMI phenomena correctly, but tended not to explain the difference between emf and potential difference or offered a rationale for their answers that was incomplete (category B). Around 30% of the students demonstrated an inadequate level of comprehension and confused the concepts of emf and potential difference in their explanations (category C). Approximately 20% of students resorted to rote memorization of laws and definitions to respond in a meaningless way (category D). Students' difficulties seem to be strongly linked to the absence of an analysis of the type of force that carries out the work in EMI phenomena. In this regard, most students still do not clearly understand the usefulness of concepts of potential difference and emf in situations involving electromagnetic induced current. Finally, our "explanatory categories" approach to students' knowledge implies that the learning difficulties found occur in a generalized way and not in a single country.

3. – A view of international physics education research at the advanced university level

Paul van Kampen from Dublin City University presented an overview of the state of the art of PER at the advanced university level. The vast majority of university PER studies have been carried out at the level of introductory physics courses, and at a local level.

PER interventions have taken place along a continuum ranging from structured to open inquiry. At the structured end (see, *e.g.*, McDermott, 2014), the curriculum developer prescribes the procedure. Typically a syllabus is covered in a linear process, one concept at a time. The teacher presents questions in a neatly tidied setting that have a predetermined outcome. These questions are typically discussed by students in a small-group setting to foster discussion, and the teacher facilitates through semi-Socratic questioning. The focus tends to be on the cognitive domain, especially on developing formalized thinking structures to foster conceptual understanding. At the more open end of the spectrum (see, *e.g.*, Duch, 1995), a syllabus tends to be covered in a non-linear fashion, with several concepts being tackled at once. The teacher typically presents a contextual problem that often does not have a predetermined outcome, and students may influence the procedures they use. Learning here to tends to take place in a small-group setting, with rotating roles assigned (Collaborative Learning). Focus is less on conceptual understanding and more on students organizing knowledge and developing research skills, and learning takes place in the cognitive, social, and affective domains.

How to progress from this solid base to the advanced university level? Since the turn of the century this field has been growing, with particular attention being paid to learning of electrodynamics, classical mechanics, quantum mechanics, and laboratory work (especially on electronics). However, this is still a nascent area of research, and difficulties in the cognitive domain to date still are under-researched. It should be a challenging area: not only do students encounter new conceptual and mathematical difficulties with new degrees of difficulty, they also need to combine skills and knowledge previously acquired in a more isolated manner. Almost no research exists on the affective domain.

In a pioneering article, Ambrose (2004) explored some possible directions of PER research at the advanced level. To discuss two examples: 1) In the context of a falling object with air resistance, where a differential equation must be set up and solved, he found that well-known findings from introductory level PER still apply: for example, students who spontaneously drew free-body diagrams did better, and confusion between velocity and acceleration was still rife. 2) In the context of a graphical representation of a vector field, he found that students struggled to apply the Stokes theorem correctly and that the visual cue of seeing vectors "curl around" a current-carrying wire led them to predict that the curl was non-zero along the path rather than at the wire. While the second type of research is likely to arouse interest among students and teachers alike, it is debatable whether there will be much interest beyond the PER community in persisting difficulties from the introductory level.

As for moving beyond the local level, there are two obvious avenues to explore, both of which build on existing knowledge. Firstly, to extend published results and combine them to make an international study (see, *e.g.*, Bollen *et al.* 2016). At the quantitative end, one may generally expect that similar reasoning patterns will be found but with different prevalences, and that new reasoning patterns may be unearthed. While this may not be a glamorous undertaking, there is potentially much value in this kind of research in terms of validating or establishing generalisability and mitigating against publication bias (see, *e.g.*, Ioannidis, 2005). Secondly, to carry out research internationally from the start, and obtain a deeper understanding of the kind of reasoning a much more varied student population employs (see, *e.g.*, Garzón *et al.*, 2014).

Where to go from here? We would propose that to build successfully on our knowledge gained at the introductory level, we need to engage in interdisciplinary developmental research that inter-relates design, development and application with research findings. This requires pedagogical knowledge of the teaching and learning of physics and mathematics, the epistemology of physics, science-technology-society relationships, and results of domain-specific physics education research. Specifically, we would advocate the development of student-centred active learning strategies in a small-group setting using multiple methodologies: quantitative methods (*e.g.* items to be evaluated numerically by students), semi-quantitative analysis of written responses, and qualitative tools such as explain-aloud interviews with students. To include as broad a range of students as possible, this research should take place in multiple institutions. The richness and diversity in culture, language, and education systems would make Europe an ideal place for this type of research to grow.

4. – Discussion and final remarks

In the symposium, different contributions in PER at the university level were presented. These talks showed some commonalities, differences and raised some questions or issues for discussion.

All contributions in the symposium showed high-quality and rigorous *research* in PER at university level. Whereas Paul van Kampen's contribution gave a critical overview of the state of the art of PER at the advanced level, the other presentations focused on the introductory level, as does most published physics education research in higher education. Moreover, all these contributions gave some insight into student difficulties. A lot has been written already, but it seems that we are still not there with our understanding of student difficulties, even at the introductory level! Although "student problems" could be seen as a common theme, the different presentations focused on different topics (emf, atomic spectra, proportional reasoning). All contributions presented results from different universities and as such tried to go beyond local impact.

During the talks, it became clear that student ideas were studied with different methods. In the work on emf and kinematics graphs, open questions were presented to students and categories of description were constructed bottom up from the data. The proportional reasoning abilities of the students were studied by analyzing student answers on carefully constructed multiple choice questions in which possible errors were put as an alternative by the researchers. Understanding of atomic spectra was studied by interviewing students, and asking both open and multiple choice questions. In this presentation, the impact of newly developed learning materials was also discussed. This brings us to a first open question, as one could wonder about the research on emf and proportional reasoning what kind of learning materials might be developed and how these might be evaluated?

Besides the question on learning materials, the following questions and issues also arise': Concerning emf, it is clear that students do not distinguish the concepts of emf and potential difference. Are we sure they understand potential difference? Is there a difference between physics majors and engineering students?

Referring to the work of Stephen Kanim and coworkers, it is not clear whether it is possible to define a "measure of proportional reasoning" and whether this correlates with "physics performance"?

Related to the work on atomic spectra and student understanding of the experimental set-up, it seems that even when studying lab work and experiments, the focus remains on the "theoretical" or maybe conceptual understanding. Do we not need to get insight in the process of experimenting itself and, if so, how could we study this role of experimental physics?

This symposium organized by the PERU-GIREP Special Interest Group aimed to present examples of high-quality research in physics education at university level and raised some issues for discussion and further research. PERU will accept contributions covering the full range of experimental and theoretical research related to the teaching and/or learning of physics. As shown in the overview presented by Paul van Kampen and the discussion developed by Mieke De Cock, we would like to experiment with developing themed "issues" on topics of interest to the PER community at university level. PER has the potential to continue to influence the dialog and investment in educational research within the disciplines of Science and Engineering.

Additional remark

Of course, PERU can only succeed with the help of people like you contributing and attending the symposium. If you are interested, please send me a note with your contact information and your area of expertise. Let me know if you have suggestions for a themed issue. We always welcome your suggestions, comments, and constructive criticism. You can email me at `Jenaro.guisasola@ehu.es` and see the web site `https://girep.org/thematic-groups/peru.html`.

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