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3RD WORLD CONFERENCE ON PHYSICS EDUCATION

Innovating physics education: From research to practice

Book of Abstracts

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Context Based Problems for Electricity Topics in Introductory Physics Courses

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Abstract. Electromagnetism topics—might seem as irrelevant for some disciplines at the first sight—can easily be related to students' home disciplines and everyday-lives by integrating relevant contexts to the topics or problems. Therefore, we would like to provide examples that integrate contexts relevant to everyday lives/future careers of students from various bachelor programs. We have been working on 18 problems in six electricity topics in various contexts. In this roundtable, we would like to work on them for further reach and practice possibilities to be able to share them with the instructors teaching introductory physics courses to non-physics majors.

1 Introduction

Many students taking a (mandatory) introductory physics course do not see the relevance of such a course. This might result in a lack of motivation for these courses. Integrating contexts from students' lives (everyday, daily/real lives) and/or their future careers—including courses in their home disciplines—might be a way to highlight the relevance of physics. Thus, some recent physics education research have been focusing on building relevance in introductory physics by collaborating with researchers from other STEM fields such as biology to design "Introductory Physics for Life Sciences" in many universities [1-5]. A noteworthy example is the University of Maryland—leading the NEXUS project and the reforms in these courses [4]. However, studies that aim to build relevance of physics for other non-physics majors are limited [6]. Thus, there is still need for concrete examples of how instructors can integrate contexts to the introductory physics courses of other non-physics majors.

Electromagnetism topics in the introductory physics courses—particularly perceived as irrelevant for many disciplines at the first sight—can easily be related to students' home disciplines and everyday-lives by integrating relevant contexts to the topics/problems. This might be a way to help students to see the usefulness of the course for their future careers and everyday lives, to stimulate their interest in the topic, and hence motivate them to learn physics. Therefore, our aim is to provide examples that integrate contexts relevant to students' everyday lives and future careers to the physics problems of various bachelor programs. In this roundtable, we would like to work on these problems and develop them further to share them with the instructors teaching introductory physics courses to non-physics majors.

We started this study by searching for contexts in the E&M course of the pharmacy bachelor program and then decided to include everyday-life contexts as we believe these are different means of building relevance, thus we believe a combination of them will enhance relevance of physics better when carefully chosen and formulated for the target group. In a preparatory phase, we conducted focus group interviews with ten instructors teaching in the pharmacy bachelor program, to determine potentially relevant pharmacy topics. Afterwards, several professors gave feedback on the problems in iterative rounds.

2 Context Based Problems Developed

We have developed 18 problems in six electricity topics. The list of the topics and the distribution of the problems to each topic are presented at the following table. Nine of the problems might be specifically relevant for pharmacy and life science majors, while the remaining nine items might be useful for the physics courses of the other groups. We would like to share these exercises with the participants of the roundtable and work on them for further research and practice possibilities.

List of problems in various contexts

Topics Contexts

1. Coulomb's law DNA strands Drug docking Pollination

Dust particles on solar panels

2. Electric field Electrophoresis X-ray (drug quality & luggage scanner)* E-reader

1. Gauss's law Membrane of a nerve cell Photocopy machine

2. Electric potential Mass spectrometry in various sciences* Thundercloud Computer Memory Chip
3. Capacitors Electroporation Red blood cell
4. DC circuits Iontophoresis Voltage divider
5. 2 different versions of the problems Acknowledgements The DiFuSeEM project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 843951. We would like to thank to the members of the KU Leuven Faculty of Science and Pharmacy Faculty for their feedback on the various versions of the problems. References [1] E.F. Redish, C. Bauer, K.L. Carleton, T.J. Cooke, M. Cooper, C.H. Crouch, B.W. Dreyfus, B.D. Geller, J. Giannini, J.S. Gouvea, M.W. Klymkowsky, W. Losert, K. Moore, J. Presson, V. Sawtelle, K. V. Thompson, C. Turpen, and R.K.P. Zia, Am. J. Phys. 82, 368 (2014). [2] C.H. Crouch and K. Heller, Am. J. Phys. 82, 378 (2014). [3] A. Nair and V. Sawtelle, Phys. Rev. Phys. Educ. Res. 15, 20121 (2019). [4] D.C. Meredith and E.F. Redish, Phys. Today 66, 38 (2013). [5] D.P. Smith, L.E. McNeil, D.T. Guynn, A.D. Churukian, D.L. Deardorff, and C.S. Wallace, Am. J. Phys. 86, 862 (2018). [6] I. Descamps, T. Moore, and B. Pollard, Phys. Rev. Phys. Educ. Res. 16, 20118 (2020).

Parallel 2 - Wroclaw/Guayaquil / 39

Utility Value Interventions to Foster Relevance of Physics Courses

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Abstract. Utility value interventions have been implemented in various STEM courses in the last decade. Stemming from the Expectancy Value Theory, these interventions have been shown to positively influence students' value beliefs, interest, and achievement. This workshop will provide a general overview of the utility value interventions by explaining various types, how these can be implemented in physics courses, making space for participants to share their experiences as a way to highlight alternative perspectives, sharing our experiences in implementation. Participants will work in small groups to discuss potential implementations for their own teaching or research.

1 Introduction

It is difficult for many students to see the relevance of physics courses that are perceived among the difficult courses. educators have been seeking ways to help students see the relevance of a course for their lives. Utility value interventions should be mentioned among the successful interventions to foster students' value beliefs in many fields especially in the last decade. These interventions are based on one of the major motivation theories in the literature: the Expectancy Value Theory developed by Eccles and colleagues [1].

According to the Expectancy Value Theory students' task values and success expectancies influence their achievement related choices such as their persistence, effort and performance [2]. Success expectancies are expectations that one can succeed at a task, while task values are beliefs about value of doing the task. Task values include intrinsic value–interest or enjoyment of a task, attainment value–importance of doing well on a task, utility value–usefulness of a task, and cost–negative consequences of task engagement [2].

2 Utility Value Interventions

Utility value interventions focus on the relevance of a course for students' lives and aim to help students perceive the course content as personally meaningful. These interventions have been implemented and shown to positively influence students' value beliefs, interest and achievement in various STEM courses such as high school mathematics [3], high school science [4], college biology courses [5], recently in a biology lab [6], and also in college physics [7]. Utility value interventions focus on the relevance of a course for students' lives and aim to help students perceive the course content as personally meaningful.

There are various types of utility value interventions:

a. Directly-communicated utility value interventions provide students information on the value of

engaging in a task. This information is usually provided by researchers, instructors or a text.
b. Self-generated utility value interventions guide students to identify the value of engaging in a task independently.
c. Critical reflection interventions ask students to evaluate others' relevance claims.
3 The workshop
This workshop will provide a general overview of the utility value interventions by briefly explaining the theoretical framework, various types of utility value interventions, and how they can be implemented in physics courses. Participants will have space to share their experiences and opinions as a way to discover alternative perspectives, before we share our experience in designing and implementing a utility value intervention.
We will also share the structured writing task that we have developed for the DiFuSeEM project and some excerpts from students' responses. Later, we will facilitate a discussion on how to interpret these excerpts and how they can be used in the physics courses to develop other types of utility value interventions. At the end of the workshop, the participants will work in small groups to discuss potential implementations for their own teaching or research. Finally, the participants will share their opinions with the whole group.
Acknowledgements
The DiFuSeEM project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 843951.
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Parallel 4 - Wroclaw / 42

The Stellarium Gornergrat: Astrophysics with your own Data

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Remote telescopes in education provide the opportunity to obtain high quality images with little effort. The Stellarium Gornergrat is such a telescope. In addition to pure observation, it offers user-friendly interface and teaching documents so that astronomical and astrophysical projects can be integrated into everyday school life without any special prior knowledge and without spending a lot of time. The contribution presents both the project and new teaching activities.

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The analysis of conspiracy theories as a stimulus to active learning

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Abstract. The development of students' critical thinking, argumentation skills and formulating hypothesis is admittedly considered an integral part of physics education. The aim of our pedagogical experiment is to develop these skills by critical analysis of selected conspiracy theory related to physics phenomena. This paper describes the theoretical background and methodological notes to activity based on students' analysis 5G technology conspiracy theory in the physics education at the upper secondary school. Finally, the paper presents didactically processed experience of implementation the activity in optional subject during distance education with 10 students.
Keywords: critical thinking, argumentation, hypothesising, activity, upper secondary school.

Parallel 4 - Wroclaw / 44

Development of a teaching sequence on physics inquiry

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Learning to engage in scientific inquiry is an important goal in secondary physics education. However, attaining this learning goal continues to be a challenge. We addressed this problem by devising and testing a teaching sequence that aims at developing students' (aged 14-15) understanding of and adherence to scientific criteria. We observed, that after going through this sequence, the students' critical attitude evolved and they developed basic understandings of how to conduct a physics inquiry. They started to substantiate the decisions made in their inquiries. The teaching sequence thus seems a suitable starting point for engaging young students in scientific inquiry.

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Astronomical Methods and the Terrestrial Climate: An Estimation of the Earth's Albedo Based on Self-obtained Data

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The significance of the albedo for the terrestrial climate
The albedo is defined as the ratio of reflected to incident light on a body in the case of diffuse reflection. For celestial bodies—such as the planets, asteroids or comets—the albedo is an essential

quantity, because on the one hand it determines their visibility and on the other hand it allows statements about their surface properties. Already the comparison of different planets and moons yields astonishing results: The albedo of the earth is about three times higher than that of the moon, which appears very bright and white. In general, the albedo of planets with an atmosphere is significantly higher than that of planets or moons an atmosphere and with a rocky surface. An exception is again the very fresh ice surface of Saturn's moon Enceladus. Here there is a clear difference to the likewise icy, but very dark cometary surfaces, whose albedo is comparable to fresh asphalt. [1]
For the Earth's climate the albedo of the planet is of very high importance. In educational contexts, the mean surface temperature of the Earth is often calculated based on the balance of incident solar energy $E_in = G_SC\ \pi R_E^2$ to the emitted energy $E_{out} = 4\pi R_E^2\ \sigma_{SB}\ T^4$ across the Earth's surface. [2, 3] Here G_{SC} is the solar constant, R_E is the Earth's radius, and σ_{SB} is the Stefan-Boltzmann constant. However, in order to obtain an approximately correct result, the irradiated energy must be reduced by a certain factor, which results just from the Earth's albedo A. It causes a considerable part of the solar radiation to be reflected before it becomes effective in the climate system. This modification for the albedo results in the effective irradiated energy: $E_{eff} = G_{SC}\ \pi\ R_E^2\ \ (1 - A)$.
The numerical value for the albedo is usually given at this point and used as a global mean value of $A = 0.3$. However, due to its importance, it seems desirable to also teach the method behind the determination of this value and to enable students at an undergraduate level to collect and evaluate their own data on the Earth's albedo.

Estimation of the albedo on the basis of self-performed measurements
The method for the determination of the Earth's albedo requires for its practical realization, besides some basic astronomical data, hardly more than the knowledge of the phase function of the moon (which is assumed to be known here) and intensity measurements for the illuminated (I_{bright}) and the non-illuminated side (I_{dark}) of the moon. The brightness of the unlit part of the lunar surface is never zero, because at any time light from the Earth (both from the atmosphere and from the surface) is scattered towards the Moon. From geometrical considerations the albedo of the earth can then be concluded from the ratio of the intensities [3]: $A \propto\ \ I_{dark}/I_{bright}$.

This contribution will focus on the handling of the obtained data, the factors influencing their quality, possible improvements in data collection as well as the general limitations and further potentials of the method. For example, the influence of scattered light is a major challenge, which can, however, be countered by means of suitable procedures if the observation conditions are good. However, this requires that there is no excessive contribution from external light sources, especially if these cause reflections within the telescope optics. The exact procedures for data acquisition, i.e., the selected patches on the lunar surface, also represent a potential source of measurement uncertainties, where a balance must be found between the effort required to analyze the data and the desired accuracy.

Conclusion
The Earth's albedo, as an essential factor for modeling the terrestrial climate, can be derived with sufficient accuracy for educational purposes from data which is obtained with simple instruments. For the evaluation, the handling of external influences on the measured intensities and the conditions of the measurement play a role above all. A discussion of the individual factors, as well as strategies for dealing with them, can provide valuable insights into the acquisition and processing of observational data.

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Parallel 10 - Wroclaw / 46

Constructing a diagnostic instrument for wave optics

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Abstract. As a part of a larger project, a 26-item Conceptual survey on wave optics (CSWO) was developed to serve as a post-test diagnostic instrument for assessing high school students' understanding of basic wave optics phenomena: interference on a double slit and optical grating, diffraction on a single slit and polarization. The construction of the CSWO included several cycles of testing and Rasch analysis. The final version of the test shows good targeting on the sample and good overall functioning.

1 Introduction

In Croatia, where physics is a compulsory subject in many high schools, the topic of wave optics is covered in the last year of studying physics, when students are 18-19 years old. The curriculum prescribes the following topics from the domain: interference on a double slit and optical grating, diffraction on a single slit and polarization. Previous PER research about students' difficulties with the mentioned domain was conducted on high school and university students [1-4] and showed that this is a difficult topic for both types of students and suggested that even the fundamental wave optics phenomena are not easily understood by them.

As a part of a larger research project aiming at developing an inquiry-based teaching approach for wave optics topics in high schools a new diagnostic instrument on wave optics (Conceptual survey on wave optics - CSWO) was developed for assessing high school students' understanding of the basic wave optics concepts after instructions. This proposal shortly describes the process of the CSWO construction and its analysis. The results suggest that the CSWO is a reliable diagnostic instrument for administration in high schools and in some situations possibly also in universities, for introductory physics courses.

2 CSWO construction, methodology, and analysis

Semi-structured demonstration interviews with Croatian high schoolers (N=27) about the above-mentioned topics after their regular school instructions preceded the process of the CSWO construction. Using the findings from the interviews and other PER studies, CSWO learning outcomes were formulated following the initial set of items that probed these outcomes (i.e., some observed students' difficulties were used for formulating distracters).

The entire process of the CSWO construction included developing and testing six versions of the instrument and each version was analysed using the Rasch model. Altogether, 61 items and 759 students (of which were 145 university students) were tested. The sixth version of the CSWO was administered in high schools (N=224) during the school year 2019/20 right after their regular instruction on wave optics which takes about 4-5 weeks, with two or three 45-minute lessons per week. Rasch analysis of each version was done using Winsteps Rasch software and main measures of the instrument were obtained (e.g., item difficulty, item and person reliability, Cronbach alpha, infit and outfit measures…). The analysis of the CSWO's final version yielded a final form of the instrument with 26 items.

3 Results and analysis

The analysis shows good targeting of the test on the sample and good distribution of item difficulties. The Rasch person reliability index is 0.78 (similar to Cronbach alpha measure, 0.77), which is an acceptable value for a diagnostic instrument. The item reliability is 0.97. Both reliability measures are indicating satisfactory degree of replicability. The theoretical construct of the CSWO seems to be empirically confirmed and shows an increase of mean difficulty with increasing cognitive complexity of the items. In general, the chosen items seem to have succeeded in producing an adequately coherent unidimensional construct from the Rasch model perspective, with good validity and reliability.

4 Conclusion

The analysis showed that the CSWO can be used as a post-test for high school students and that the instrument shows good structure and functioning. The results of the CSWO tested on Croatian high school students suggest that the most difficult aspect was forming explanations and applying knowledge to real-life phenomena. This points to the students' lack of good models of basic wave optics phenomena, since they resorted to explaining them by combining many fragments of knowledge and chose the explanations that are consistent with the previously identified difficulties in PER.

Acknowledgements

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Parallel 4 - Wroclaw / 47

Investigating high school students' difficulties with wave optics

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Investigating high school students' difficulties with wave optics

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Abstract. Preliminary results of the 27 demonstration interviews about basic wave optics phenomena (polarization, interference, and diffraction of light), held with Croatian high school students in 2018 and 2019 will be presented and discussed using the knowledge-in-pieces perspective.
1 Introduction
Croatian high school students encounter wave optics during their final year of high school education (aged 18-19), where wave optics is typically taught in ten 45-minutes lectures. During the teaching, double slit and optical grating interference, single slit diffraction and polarization of light are covered. To probe Croatian high school students' understanding of basic wave optics phenomena after

instruction, we conducted a series of demonstration interviews. The preliminary findings will be presented and discussed within the knowledge-in-pieces theoretical framework.
2 Literature research and theoretical background
The previous research on students' understanding of wave optics phenomena was mostly conducted on university students and showed a lack of students' understanding of wave optics. For example, students failed to differentiate situations where geometrical and wave optics are applicable or when wave model or modern physics concepts (i.e., photons) are applicable [1].
Knowledge-in-pieces framework describes students' knowledge as consisting of various small elements, that are activated depending on the situation. The smallest indivisible elements of knowledge are called phenomenological primitives (p-prims) [2]; larger cognitive structures are called conceptual resources [3]. Activation of cognitive resources can lead to the correct, or incorrect conclusions, depending on the situation.
3 Methodology
Between the springs of 2018 and 2019 demonstration interviews with 27 high school students (aged 18-19) were conducted. Students were shown four typical experiments regarding wave optics (double slit/optical grating interference, single slit diffraction of light, and experiment with two polarizers) and they were asked for their predictions, observations, and explanations of the observed patterns. The interviews were then transcribed and analyzed.
4 Results
The analysis of the interviews showed a variety of students' difficulties regarding polarization of light. For example, students often remembered visual representations of polarization typically shown in schools, but they did not remember (or know) what those visual representations stood for. Some students confused the direction of the electric field oscillation with direction of light propagation or tried to explain polarization using the resources from geometrical optics [5].
When it comes to interference and diffraction of light, students were often unable to predict or explain the patterns obtained on the screen when red laser light was incident on a double slit, single slit, or optical grating. Some student difficulties may have been caused by misapplication of cognitive resources such as e.g. possibly applying the p-prim one cause produces one effect, when they expected one bright spot on the screen for each slit that was illuminated with laser light. For example, some students predicted that there would be 80 bright spots on the screen from optical grating with 80 lines/mm or two spots from the double slit. Other possible misapplications were also identified in student answers,
5 Conclusion
It is important to see what students retain after regular school instruction on wave optics. We identified many problems in student understanding of wave optics and tried to explain them through p-prims or conceptual resources that they activate in the process on the cognitive level.

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Parallel 7 - Wroclaw / 48

A learning environment for pre-service physics teachers on how

to diagnose students' conceptions not covered by physics education textbooks

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To date, there is a lack of (research on) learning environments for pre-service physics teachers that allow them to learn about and practice diagnosing students' conceptions that are not covered by physics education textbooks. In this study, we developed and piloted such a learning environment. Since coping with the diagnostic process is particularly demanding for preservice physics teachers, our accompanying research aims to identify learning barriers within our developed learning environment. Our contribution presents the design of the developed learning environment and reports preliminary results of our accompanying research.

Parallel 4 - Wroclaw / 49

Plato and modern physics

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I will look at Plato from a point of view of a particle physicist. I find his philosophy surprisingly relevant for the current development in our field, and, vice versa, modern physics offers precious input into deep philosophical questions, in particular about the role and nature of beauty, the quality appreciated in various forms by all people.

Parallel 1 - Wroclaw / 50

The Simplicity-Completeness Issue In Physics Explanations Discussing The Rainbow With Student Teachers

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The Simplicity-Completeness Issue In Physics Explanations
Discussing The Rainbow With Student Teachers

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Abstract. This study explores the extent to which student teachers (STs) of physics can detect consequential gaps in a given explanation (RQ1), and the extent to which they sacrifice simplicity for completeness when designing an explanation for a given audience (RQ2). A very limited explanation of the primary rainbow ("one ray") was discussed with 33 STs, using two successive questionnaires. The STs were often unaware that the "one ray" explanation was deeply incomplete (RQ1), and the dilemma between simplicity and completeness often remained unresolved after a critique

of the explanation's incompleteness (RQ2). The implications for teacher preparation are finally discussed.

1 Introduction
This paper adresses Shulman's questions [1] 'Where do teachers' explanations come from? How do teachers decide what to teach, how to represent it?' (p. 8). To articulate the strengths and weaknesses of an explanatory text, it has recently been proposed [2] to use grids based on explicit criteria. The present study focuses on the criterion of completeness and two other criteria that may seem a priori incompatible (simplicity) or congruent (coherence). Focusing on these criteria, the study investigates the extent to which student teachers (STs) detect consequential gaps in a given explanation, and how this influences their decision-making process. The chosen topic (the rainbow) was limited to the case of the primary rainbow.

2 Previous research, rationale, and research questions
How STs make decisions about explanations that they will use in teaching a given audience can be understood as a two-step process: a critical analysis of explanations commonly applied to the topic in question and a decision based on the perceived benefits and risks of each candidate explanation [3]. It is common to observe a conflict between completeness and simplicity. In the present study, the participating STs were introduced to critical analysis as the detection of gaps in an extremely limited explanation of the primary rainbow. Particular attention was paid to one of these shortcomings, which consists in considering only one particular incidence of a solar ray on a drop to explain the value of its deflection ("one-beam" explanation). Such an explanation is logically invalid since another incident ray - for example a diametrical ray - would lead to a different deflection - if any at all. The two research questions are: (RQ1) To what extent do STs recognise the gaps in this incomplete explanation?; (RQ2) Do participants consider it necessary to provide an explanation that is more coherent and less simple—in this case, for first-year university students—and why?

3 Experimental design
The participants were 33 student teachers (STs) at the end of a master's degree preparing for teaching physics and chemistry. A first questionnaire (Quest. 1) explored what additional explanations they thought first-year university students would need beyond the "one ray" explanation. Sent after the first questionnaires were returned Quest., 2 begins by explaining that the specific incidence considered in the "one ray" explanation corresponds to a maximum brightness of the reflected beam. Participants were then asked what value they assigned to the explanation of this point to ensure a good understanding of the rainbow in the target audience. The comments in response to Quest. 1 and 2 were grouped on the basis of a thematic analysis.

4 Main results and discussion
Only one participant (out of 33) explicitly pointed out the logical incompleteness of the "one ray" explanation, while many other complementary explanations were requested. This clearly indicates that the issue of logical incompleteness is hardly detected in this group even though it invalidates the explanation. With regard to the value of completing the "one ray" explanation as proposed in Quest. 2, almost all respondants declared that it was important, but several comments expressed ambiguous positions such as "So the diagram is still right, it simply omits (for simplicity) the infinite number of rays that are diffracted" and several hints suggest that the simplicity-coherence dilemma was not easily resolved. This research indicates that STs would benefit greatly from a frequent practice of critical multi-criteria diagnoses and explicit consideration of the interrelated issues of simplicity, consistency and completeness. Further research is needed to optimise teacher preparation in this regard."

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Parallel 6 - Hanoi / 52

What can be Learned from Physics Textbooks

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Physics textbooks have been generally viewed as important tools that provide reliable information that supports and enhances students' understanding of critical concepts. This paper investigates whether physics textbooks have met these goals, and how well they have adapted to inquiry-based teaching and on-line learning. The presented study is a literature review about physics textbook evaluation. Research concerning physics textbooks from different countries are discussed and analysed, and a broad overview about aspects that influence the efficacy of physics textbooks are presented. Studies investigating the importance and influence of digital textbooks (and similar online resources) are also analysed.

Parallel 2 - Wroclaw/Guayaquil / 53

Education and Formation: STEM in the Tradition of Alexander von Humboldt

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Alexander von Humboldt is known as a great naturalist and explorer who wanted to understand and describe the explored space as a whole in many different ways. More than anyone else, he was able to view and examine scientifically correct facts additionally under criteria of aesthetics. Thus, in many respects, he was a pioneer of an interdisciplinary way of working and researching, which is also exemplary for today's teaching.

The central pivot for Humboldt's work is formed by the STEM subjects astronomy, chemistry, geography, forestry and physics. Some historical measurements from the respective disciplines will be presented and compared with current measurements. While in his time Humboldt was only able to determine heights by means of a barometer and by calculating angles, today remote sensing methods such as the stereoscopic evaluation of (digital) aerial image pairs and the calculation of digital terrain models as well as radar data are available. Technological progress makes possible not only the calculation of the earth's surface, but also the determination of phytomass. We are able to reproduce Humboldt's measurements and to perfect them with modern methods. In the sense of the scholar, regularities and regularities can be represented cartographically, among other things, which are to be thematized in science and technology lessons. Furthermore, they offer points of contact for neighboring sciences and bear witness to Alexander von Humboldt's extensive work and scientific foresight.

Analogous to the wealth of material in the STEM subjects, Humboldt was able to grasp the totality of a landscape with all its phenomena and processes and to draw conclusions from it that are still valid today. For example, the mapping and publication of the three-dimensional distribution of vegetation, the global change of the earth's magnetic field, the temperature change with the geographical latitude or the ocean currents go back to him.

The breadth of Alexander von Humboldt's impact makes him an iconic figure as a figure in the various STEM subjects, creating occasions to advance integration while respecting the respective sciences.

Parallel 5 - Wroclaw/Guayaquil / **54**

A teaching-learning sequence on colour in the context of a motivational stage for high school students

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In this contribution we present a Teaching-Learning Sequence (TLS) on colour performed in a University setting with a sample of N=42 18-year old high school students. Based on previous research, the TLS focuses on the integration of experimental activities with low cost materials, on developing a solid understanding of the connection between the physics and physiology of colour, and on experimental activities which help students to clearly differentiate between additive and subtractive color mixing. Finally, thanks also to the inclusion of advanced topics such as photonic crystals and plasmons, the sequence has a significant motivational value.

Parallel 9 - Hanoi / **55**

Graph Comprehension of Simple Harmonic Motion and Understanding among Japanese University Students

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Abstract.
A computer-based test was conducted for Japanese university students to clarify their understanding of the graph of simple harmonic motion (SHM). The survey questions were based on the previous studies by P. Wattanakasiwich et al. with an eye-tracking system. Although the survey method was completely different, the results for Japanese university students showed a shape close to the Gaussian distribution. In addition, since similar survey results were obtained, the survey problem of SHM could be validated.

1.Introduction

Physics deals with the laws of natural phenomena, and there are various ways of expressing them. One of the difficulties for learners of physics is understanding this variety of expressions, which not only allows learners to understand that one phenomenon can be expressed in various ways, but also allows them to freely translate into different expressions. The purpose of this study is to clarify learners' difficulties by focusing on simple harmonic motion (SHM), which requires understanding of physical phenomena in a graphical representation.

2.Research Method and Research Subjects

In previous studies by P. Wattanakasiwich et al. [1] [2], the authors created a multiple choice a computer-based test (CBT) that expresses physical phenomena related to simple harmonic motion (SHM) using graphs and formulas, and used an eye-tracking device to solve the difficulties of learners. The purpose of this study is to use a Japanese translation of this survey problem, and conduct a survey mainly for first-year university students in science who do not specialize in physics and compare it with the results in the previous studies in Thailand. The subjects of the research are 139 students in the department of chemistry and 100 students in the department of mathematics who are taking introductory physics based on calculus. Classes were held separately in the two departments, but the same professor taught them.
Due to the COVID-19 pandemic, it was not possible to conduct a face-to-face survey using an eye-tracking device, so we decided to conduct a survey online using Google Forms. However, from the viewpoint of fraud prevention such as leaking problems and solving problems with friends, the investigation time was set to 20 minutes and problems were presented at random. We also explained that although points will be added to grades by taking the survey, the points will not change depending on the grade. The survey was conducted after the sixth round (May 2021) of 15 (90 minutes per round) in the first semester of 2021. Since SHM was not dealt with in class, it falls under the pre-test classification.

3.Results

Of 239 students, 204 participated in the survey. Regarding their high school course history, 158 students took both basic physics and physics, and 23 students took only basic physics; three students did not take either courses, and 20 students did not answer the questionnaire. The 12 survey questions were each scored with one point. Here, in order to exclude differences between high school course history. Fig. 1 shows the results for 158 students who took basic physics and physics. The horizontal axis is the score, and the vertical axis is the number of students. The average score was 5.2 points.
The results of this study were compared with the previous study, as shown in Fig. 2, with the question on the horizontal axis and the correct answer rate on the vertical axis. Here, some results were not posted because it was not mentioned in the previous study or because of our original problem.

Fig. 1 Score distribution (n=158) Fig. 2 Correct answer rate (n=158)

Firstly, regarding understanding of SHM in graph representation, it is not possible simply to compare with the previous one. Since the percentage of correct answers was higher overall in this study result, except for question 5 (Axis change*), which changed the question options, we consider that the survey method has contributed significantly.
Looking at the percentage of correct answers in this study and previous one, the tendency in the percentage of correct answers is similar, except question 2 (Pull) and 3 (Hard spring). Considering that the distribution of the correct answer rate in this study resembles a Gaussian distribution, it is considered that the survey problem of the previous study is appropriate as a problem to investigate graph comprehension in SHM.

4.Summary and Remarks

From the results of this survey on understanding SHM graphs among university students who are taking introductory physics based on calculus, many questions tend to be similar to the results of previous studies in Thailand. In the future, in order to clarify the understanding of graphs and formulas, we would like to clarify how to understand the SHM graphs where learners can write equations and draw graphs by conducting a survey using an eye-tracking device.

Acknowledgements

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Parallel 3 - Hanoi / 56

Measurement of the Refractive Index with PhET

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Abstract. In distance education, we gave students the assignment of measuring the refractive index. Students watched a film on refraction between transparent material and air, and measured the refractive index from the relationship between the angle of incidence and the angle of refraction. There is a calculation of the critical angle as a means of verifying whether or not the obtained refractive index is appropriate. This time, not only the calculation of the critical angle but also the PhET simulation Bending Light was used. We discuss the effect of using PhET for verification.

`Introduction`

In physics, more than only one representational format is often used to convey information and support knowledge construction [1]. It is well known that the use of multiple representations can enhance learning. PhET simulations were developed to support active learning [2]. Due to the COVID-19 pandemic, Japanese universities have been forced to provide distance education. The purpose of the study was to find out how effective the use of PhET is for students on the introductory physics course at a certain university. We report on the effect of using PhET for verification in the refractive index measurement.

`Research Method`
`Survey Subjects`

As a part-time lecturer, one of the authors taught introductory physics classes (algebra-based physics) in the first semester of 2020 and 2021 at a certain university in the faculty of home economics. There were 66 (2020) and 38 (2021) students. The students' high school physics courses were examined. In Japanese high schools, waves traveling on a straight line are treated in basic physics, while waves traveling on a plane are treated in advanced physics. The numbers of students taking advanced physics, which includes the content of light refraction, were 16 (2020) and 4 (2021).

`Assignment in Light Refraction`

Students were asked to measure the refractive index following a film [3]. Refraction occurs when light enters a different medium. The index of refraction is the ratio of how light is refracted. Usually, the refractive index obtained can be verified by calculating the critical angle.

`Using PhET Simulation for Verification`

It is difficult for students to find the refractive index following the experimental film, as the students are unfamiliar with the index of refraction. The critical angle is calculated after the refractive index is calculated, for verification, but this calculation is also difficult. We therefore focused on the PhET simulation Bending Light, which can verify the refraction of light by the refractive index [4]. In 2020, students used PhET for verification to measure the index of refraction, while in 2021, they were given a two-step refractive index measurement to clarify the effect of PhET. That is, it was confirmed whether the refractive index was measured correctly at the stage where PhET was not used.

Results and Conclusion

We analyzed the task evaluation of 58 (2020, with PhET), 34 (2021, first step without PhET), and 32 (2021, second step with PhET) students. From the results in Table 1, it can be seen that PhET is effective for this assignment.

Table 1. Measurement of the refractive index(2020,2021)
2020 N=58 2021 1st* N'=34 2021 2nd N"=32
Measured correctly Understanding deeply 38 9 19
Not understanding deeply 9 11 6
Measured incorrectly 11 14 7
* We did not suggest that students use PhET in the first 2021 assignment.

In 2020 and 2021 (second assignment), after submitting the assignment, a further questionnaire was conducted. The purpose of the questionnaire was to determine whether PhET was useful for determining the refractive index in the experimental film. It can be said that the answers show that the simulation functions very effectively when used properly for verification (Fig. 1).
By using PhET simulations, it is possible for students to verify the refractive index obtained.

Fig. 1. Bubble chart showing questionnaire results obtained after submitting the assignment. We asked the students was the assignment difficult and was PhET useful, on a scale of 1 to 5 each.

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Parallel 6 - Hanoi / 57

Survey of Newton Mechanics Conceptual Consistency using Multiple Representations for High School Students

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Survey of Newton Mechanics Conceptual Consistency using Multiple Representations for High School Students

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Abstract. For students who are beginners in physics, it is difficult to understand physics phenomena using highly abstract expression like equations. This is because physics generalizes phenomena by using multiple representations. In this study, we clarify the difficulties that second-year students at high school have in transforming between multiple representations. For this purpose, we conduct a task to represent physical phenomena described by equations in sentences and a survey question based on R-FCI, and describe the results.

Background and Research Purpose

For beginners, it is difficult to understand physics phenomena using equations [1]. For example, they can memorize equations and insert them, but they may not be able to explain what the equations and physical quantities mean. In this study, we clarify the difficulties that appear when high school students taking basic physics classes transform between multiple representations to help them understand phenomena using highly abstract equations [2].

Research Method

This study targets 102 second-year high school students, where the first author has been teaching basic physics since April 2021. The study was conducted from April to July 2021.
In April, we conducted a preliminary survey on the concept of force, students' attitudes to science, and students' experience with experiments using sensors [3]. In May, a mid-term examination was held, which included questions on reading physics phenomena described in texts and representing them with equations. In addition to the mid-term examination, students were asked to read physics phenomena described in writing and express them using diagrams and physical quantities. In July, we conducted a survey on the concept of force using multiple representations. By examining the correlations between these representations, we examine the changes in students' understanding of physics phenomena as a result of teaching them using multiple representations.

Results and Discussion

At the end of the first semester, we conducted a survey on the concept of force using multiple representations of the upward throwing of a ball. The representations used were (1) arrows showing the force working on the ball (multiple choice); (2) a drawing of the force working on a ball after being hit by a bat and a written explanation of the force; and (3) a graph of the relationship between the force acting on the ball and time (multiple choice). The results showed that students' naive concepts were more complex and inconsistent than expected. In (1), students had 24 response patterns, which was quite complex (Fig.1). This was due to a combination of the naive concept that the force is applied to the ball by the hand even after it is thrown, and the naive concept that there is no force acting on the ball at the highest point. In addition, about 99% of the students were inconsistent between these results and the graph they chose in (3).
In (2), about 86% of the students described the force that the ball receives from the bat, and about 43% of the students described the effect of gravity on the ball. Comparing the results of the analysis of (2) and (1), about 93% of the students, in selecting the arrow of force and drawing it, were consistent in expressing the false concept that the ball receives force from the hand and bat while it is rising. The representation of the correct concept of gravity acting on a ball was consistent for about 86% of the students. Furthermore, comparing the results of (2) and (3), the consistency of the representation of the force versus time graph (F- t graph) and the force diagram was about 48% for the incorrect concept of receiving an upward force and about 56% for the correct concept of gravity acting on the ball. Thus, regardless of the correctness of the students' conception of the force acting on the ball, most of the students were consistent in the representations of the force arrows they drew and the representations of the force arrows they chose, and about half of the students were inconsistent between the representations of the force arrows they drew and the F- t graphs they chose.

Summary and Future Prospects

It is said that it is effective to use multiple representations when teaching students to understand a physics phenomenon, but it is necessary to use multiple representations for each event step by step, not to represent a series of phenomena from the beginning. We would like to clarify, from the viewpoint of individual optimization, which scaffolding should be used between expressions when students convert from concrete to abstract representations.

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Parallel 1 - Wroclaw / 58

The Science Of Constructing Models To Foster A Deeper Learning

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see attached document

Parallel 5 - Wroclaw/Guayaquil / 59

Collaborative Activities for University Physics during COVID and for post-COVID Times

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An active-learning workshop is offered to provide examples of a collaborative group-learning pedagogical environment for introductory physics at the university level. Participants will engage in various hands-on and minds-on activities that will illustrate how such a dynamic classroom can transform the strategy for teaching physics in university classes. A discussion about the benefits and challenges will help guide the participants in adopting this teaching method in their own physics classes, either in online mode or for in-person instruction.

Parallel 7 - Wroclaw / 60

Insights and Reflections in Physics Teaching and Learning at High School and University

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Online Symposium. Organized by GTG Physics education Research at University-PERU

Abstract. Many countries are experiencing significant problems with engaging students with the advanced study of physical sciences. Where this is the case, it is a source of significant concern. Whilst science and engineering are often seen as interesting to young people, such interest is not reflected in the learning outcomes in science and engineering degrees that have little success in the

early years. The reasons for this are complex but need to be addressed. More attempts at innovative curricula and ways of organising the teaching of science that address the issue of low student motivation and learning are required. This Symposium presents emerging topics in physics teaching and / or learning as an effort to innovate and improve the research-based physics education.

Parallel 4 - Wroclaw / 61

Symmetries: Interdisciplinary Project-Based Learning in High School.

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Abstract. Project-Based Learning methodology has been used to experiment with high school students' interdisciplinary learning crunch focused on symmetries. Students were involved in some highly symmetric solids' buildings. Symmetry has been investigated in Art, Philosophy, and Mathematics by using ICT, too. Finally, students built some symmetric electrical networks, and they verified the main symmetric properties through the equivalent resistance measurement.
The students developed content knowledge as well as critical thinking, collaboration, creativity, and communication skills.
The hands-on experience increased students' motivations and participation, making them more involved in the educational process.
1 Introduction
Interdisciplinarity plays an important role in various fields for the following reasons:
a) The first step is to get students to reveal their abilities and then guide them to define their place in society.
b) it is also necessary for students to learn before acquiring any particular body of knowledge.
c) lastly and more generally, it is important to allow students to find themselves in the present-day world, to understand and criticize the flood of information they are deluged with daily.[1]
In interdisciplinary tasks, students' attitude to generalize disciplinary knowledge to new application contexts is encouraged naturally. The European Union recently published recommendations to integrate all scientific disciplines with their applications in technology and engineering and with artistic expressions (STEAM). Benefits would be, for example, the positive effects of art in interaction with different disciplines, including mathematics and physics, from the affective and motivational point of view. Moreover, it fosters the development of creativity and critical thinking. Here, we focused on the integration of Mathematics, Arts, Philosophy, and Physics in high school [2]. Starting from the symmetry properties of some highly symmetrical solids, students were asked to "reinvent" mathematical concepts [3] by counting and measuring equivalent resistances in some specific symmetric electrical networks. [4]. We asked if this Methodology helps students to understand Physics better, using resources from several disciplines.
2 Project-Based Learning
Our theoretical framework is based on Gold Standard PBL [5]. Students' projects are focused on key knowledge, understanding, and success skills, as following in figure, taking into account all the seven essential elements: A Challenging Problem or Question, Sustained Inquiry, Authenticity, Student Voice & Choice, Reflection, Critique & Revision, Public Product.

Fig. 1 Seven Essential Project Design Elements
3 Activities
The Project involved about 60 high school students. A qualitative analysis has been carried out through questionnaires concerning the student's motivation, engagement, and participation.
The activities have been divided into several steps. As the first step, cardboard models of Platonic solids were produced. The students observed some symmetries properties, analyzed the artistic features, and considered the Art and Maths history, as in De corporibus regularibus (Piero della

Francesca) and De Divina Proportione (Luca Pacioli, Niccolò Tartaglia , and Rafael Bombelli). In the second step, combinatory and metric properties about highly symmetric solids have been studied by following the Fedone (Plato). Moreover, students realized in the lab some resistive networks as Platonic solids, whereas the resistances covered the edges of these solids and measured the equivalent resistance. In the third step, a mathematical model was designed to compute the equivalent resistance using specific algorithms (Laplace, Ductch) and software Mathematica. Finally, a comparison has been carried out between the theoretical results and the experimental measurements.
4 Conclusions
We deduced that students learn physics more quickly, are more motivated to ask questions and seek resources from different disciplines if they are involved in a challenging real problem.
Furthermore, by working on concrete projects, students acquire autonomy and responsibility, develop skills and apply knowledge, and learn meaningfully.

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Parallel 7 - Wroclaw / 62

Education of prospective physics teachers during spring 2020 COVID-19 lockdown

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Abstract. Most European countries found themselves in a complete lockdown in March 2020 due to the COVID-19 pandemic. Classes were transferred to online environments, even lab and school practice courses for prospective physics teachers. We investigated students' and instructors' experiences with these two courses and their reorganization at universities in Croatia, Austria, and Germany by means of interviews and questionnaires. Both students and instructors believe that well-guided home experimentation used as a replacement for lab work has increased their creativity and boosted students' confidence. In contrast, reorganized school practice courses offered no benefits and if possible, should not be held online.
1 Introduction
During the first COVID-19 lockdown, laboratories for prospective physics teachers and school practice courses were transferred to an online format. The goal of this research was to investigate and compare different online formats for these two courses at three universities in Croatia, Austria, and Germany. We aimed to do so by answering two research questions: 1. What are students' and instructors' experiences with the online laboratory courses for prospective physics teachers during the

lockdown? 2. What are students' experiences with school practice courses during the lockdown? Answering these two questions can help to guide course instructors to better organize these courses for the following lockdowns.
2 Practical courses for prospective physics teachers
Lab courses for prospective physics teachers teach students to design and perform experiments by combining pedagogical content knowledge (PCK) [1] and experimental skills with interactive teaching techniques [2]. School practice courses prepare students for their work as physics teachers in schools by acquiring hands-on experience by working and interacting with students.
At the three mentioned universities, during the first COVID-19 lockdown, reorganization of these courses included e.g., doing home experiments and using simulations for the lab course or preparing teaching materials for students and participating in virtual classrooms for the school practice courses.
3 Methodology
Our interview and questionnaire research took place during the summer semester of 2020. First, students attending the lab courses for prospective physics teachers and school practice courses (N=12) were interviewed and afterwards, a questionnaire was prepared and distributed to students attending these two courses (N=118). Last, results from the interviews were also used to formulate an open-ended questionnaire for instructors of the lab course for prospective physics teachers (N=8). The interview data was structured and summarized by rules of qualitative content analysis [3]. The questionnaire data underwent standard frequency analysis.
4 Results
Students experienced positive and negative aspects of the online lab course. Some positive aspects include managing their own time for performing home experiments, being creative while designing and doing home experiments, and now believing that more experiments can be done in schools than previously thought so. The comparison between the three different universities showed that students, who did not receive support and guidance with home experimentation (such as working with an online partner and/or discussing their experimental designs during videoconferences) generally did not like performing them and thus did not experience the benefits of doing them. A negative aspect emerged concerning the enhanced workload and time consumption. This aspect was also stressed by most of the instructors.
During the reorganized school practice course, majorly all students attending school practice courses reported working on creating tasks and materials for school students. They usually conducted online lessons using videoconferencing, worked with the schools' learning platforms and/or recorded educational videos. Students did not see many benefits with the reorganized school practice since they could not experience the classroom environment.
5 Conclusion
Analysis of the data showed positive outcomes concerning the adapted lab course from which we conclude recommendations for future courses: For instance, students' creativity and confidence about designing and performing experiments could be strengthened by home experimentation, if they are supported and guided during the experimental process. In contrast, not many benefits can be ascribed to the reorganized school practice courses.

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Parallel 6 - Hanoi / 65

Active Learning on Paradoxical Phenomena in the Fluid Pressure

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Abstract. Several cases studies for the development of a simple experimental method for fluid pressure are reported. It is included how to carry out a home-made experiment for active and deep learning using paradoxical phenomena on those. In this study we proposed a simple experimental equipment at home using inexpensive 100-yen store items recent information and communication technology(ICT) tools for clear pressure visualization. We present practical examples of modern reconstructions for historically valuable teaching methods in the Meiji Era, those resolve such as E.H. Graf's "Buoyancy Paradox" around fluid pressure by finding suitable experimental methods with bargains goods.

1 Historical investigation from the Archimedes principle to the Pascal's Law

We are developing ICT-based active learning (AL) modules[1] in science education using hands-on tools for modern reconstructions of historically valuable teaching materials of the Meiji Era via comprehensive studies for students' notes on Newtonian Mechanics, etc.

In this paper, we focus on fluid pressure in static fluid mechanics. Using our hands-on suction valves, we first conduct some historical investigations on the Archimedes' principle and the Pascal's Law in static fluid mechanics for a clear understanding of the E.H. Graf's "Buoyancy Paradox" [2]. In "On Floating Bodies," given by Archimedes, he suggested that (c. 246 BC): Any object, totally or partially immersed in a fluid, becomes lighter (buoyed up) due to a force equal to the weight of the fluid displaced by the object. Further, in ref.2, E.H. Graf stated that: "A solid heavier than a fluid will, if placed in it, descend to the bottom of the fluid, and the solid will, when weighed in the fluid, be lighter than its true weight by the weight of the fluid displaced." However, the fluids described by Archimedes are not self-gravitating since he assumes the existence of a center point M, toward which all things fall (Fig. 1-A). Therefore the meaning of the bottom of the water fluid not well defined as Fig.1-A in Archimedes' Era.

Blaise Pascal established not only the concept of "fluid pressure" but also the method of creating a vacuum at the top of the mercury column to measure pressure. It is especially noted that in contrast to Graf's statements in "Proposition 7", verifications on Fluid Pressure in the case of Pascal's demo as shown in Fig. 1-B, under of the W (Wood in Piston cylinder) has no buoyancy due to no water, at the bottom in Fig. 1-B&C (our transformed version of B), because of no fluid water beneath W. Then Graf's statements create serious contradictions named "Graf's Buoyancy Paradox" with no upward pressures in Fig. 1- B&C. In the next section, we try to make a fundamental clarification to resolve "Graf's buoyancy Paradox" weighed in fluid, but no water beneath W.

This "Buoyancy Paradox" has been hot topics of science education mailing list in the past several years and has attracted a great deal of attention, particularly as an error in questions of entrance examinations for high schools. However, those serious contradictions are far

Fig. 1 Archimedes' Earth and Pascal's demos on suction wood in piston as B and C.

from being completely solved yet, and fundamental clarification of those is strongly expected.

2 E. H. Graf's "Buoyancy Paradox" and clear experimental solutions for his contradictions

In this section, we try to clarify E. H. Graf's "Buoyancy Paradox". He wondered what if the object is resting on the bottom and there is no fluid beneath it. He determined "the apparent static weight" by following step-by-step ways as Fig. 2-X [2]. 1) Place the submerged object on the scale and record the reading.

2) Remove the object and record the scale reading. 3) The difference in readings is the apparent weight. [2]

Fig.2 Graf's apparent weight and Ours Demos using suction-caps in A,B,C,D states

Furthermore, "Graf justifies his procedure" because it is similar to that which we would use to determine an object's true weight in the air. It always becomes lighter than its actual weight by the weight of the fluid displaced even if there is no buoyancy fluid beneath it, i.e., it is a serious contradiction! However, the critical history for understanding buoyancy by Pascal's Law on the object in fluid is well investigated in "Mach Mechanics [3]". In our talk, we demonstrate AL methods for fluid pressure focusing on the deeper conceptual understandings on key points of " buoyancy paradox" using the hands-on experimental tools shown Fig.2-Y and we investigations on fluid mechanics from Archimedes to Galilei, Pascal, Mach's books.

Now we show some typical examples of modern reconstructions for historically valuable teaching methods in the Meiji Era to resolve thee paradoxical phenomena around fluid pressures. We report on some new practices for developing the visualized ICT-based AL through demonstrations via such

suction valves; namely, a home-made suction cap made from the top cut part of a PET-bottle (Fig.2-Y), where the bottom is covered with silicone for sealing, and the top-cover has a valve structure for pressure reduction. The demonstrations of resolving the various paradox on fluid pressures are achieved by finding the new experimental methods to visuarize both pressure values inner and outer sides of suction caps for Fig.2-Z; A~D states. We show that it's impossible to justify the "Graf's procedures" in the case of B, C, D states.
3 Conclusion
If the fluid is divided by the boundary of the silicon sealing of the suction cap (Fig. 2-Y), the reference value of fluid pressure will be different in each divided area. Therefore, the pressure values inside and outside any suction caps in states A, B, C, and D (Figure 2-Z) will be different. We present the development of experimental methods using such a visualization sensor, and the importance of deep learning of paradoxical phenomena using ICT-based AL.

Acknowledgements
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Parallel 8 - Wroclaw/Guayaquil / 66

Implementation of radioactivity in primary school physics lessons

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The paper presents the results of the study on the knowledge of radioactivity among primary school students. For the purpose of the study, a teaching unit on radioactivity was designed. Data were collected using an online instrument: knowledge test and questionnaire. 70 primary school students were included in the study and the pre-post design was used. The results show an improvement in knowledge about radioactivity after a teaching unit on radioactivity and no change in views about the peaceful use of nuclear energy.

Parallel 8 - Wroclaw/Guayaquil / 67

Learning how to debunk climate change myths during teacher education

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In the "post-truth" era, where misinformation and fake news are increasingly present and young people rely on social media as information sources, teaching students strategies to identify such

online misinformation becomes pivotal. However, in order to support students, teachers need to be professionalized to teach such strategies. Hence, we developed a learning environment for physics pre-service teachers where they are supported to learn how to spot and debunk misinformation and myths about climate change. There, they are practicing a specific technique called prebunking in order to pre-emptively inoculate their future students against online misinformation regarding socially controversial topics.

Parallel 1 - Wroclaw / 68

Towards an Early Physics approach for secondary students

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In times of distance learning mode, some traditional approaches to teach Physics in the secondary level of instruction have particularly disclosed their limits. In connection with that, a rather diffused lack in the students' scientific abilities has also been revealed. Developing teachers' awareness towards these limits and exploiting their PCK, we stimulated them to get involved in a new teaching approach that accounts for some features peculiar to the initial steps in Physics studies. For that reason and for the analogy with a similar and widely known approach proposed for Maths studies, we name it Early Physics.

Parallel 9 - Hanoi / 69

An Assessment Rubric for Future Teachers Ability to Design Experiments

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An Assessment Rubric for Future Teachers Ability to Design Experiments
Ioannis Lefkos, University of Macedonia, Greece

Abstract. Designing an experiment is a challenging task for most learners. In this work, we are proposing the use of a rubric for the assessment of future Teachers' ability to design experiments. The rubric comprises 6 dimensions and 3 levels of success of the learners' designs and is facilitated by giving a paper & pencil task and a specially designed worksheet. Results from a pilot study revealed that using the rubric we were able to identify the learners' difficulties. This kind of task and assessment scheme can easily be applied to a variety of educational conditions.
1 Designing experiments
Laboratory work and students' engagement in inquiry practices are highly appreciated in science education as a means of promoting students learning [1]. Experimental work is a central component of inquiry-based approaches and the inquiry learning cycle [2]. However, the process itself of engaging students in experimentation is not universally defined, and a variety of ways of describing it have been proposed most of them proposing a three stages process. The first of the stages is usually called "design" and is the preparatory phase where one properly designs an experiment in order to answer a research question [3].
Designing an experiment is probably the most challenging stage in experimentation [4] and various

difficulties have been identified in learners of all ages, ranging from primary school to university students [5]. We considered it to be a scientific "ability" since reflection and critical processes have to be employed by the learners [6]. Research on the ability to design experiments at the university level is mostly focused on Engineering or Science majors [6,7], but assessing and developing this ability of future Primary School Teachers (PST) is also important [8] in order to promote their engagement in similar tasks with their students.
Concerning the assessment of the ability to design experiments, there is a variety of proposed methodologies like rubrics, pen & paper tasks, questionnaires, or interviews. From the aforementioned, rubrics can also be used as a scaffold for the development of the ability to design experiments [6] and this is the approach used in this work.
2 Assessing the dimensions of designing experiments – a pilot study
Designing an experiment comprises a set of sub-abilities or "dimensions". Adopting a modified version of a scheme used elsewhere [9], in this work we propose using 6 dimensions and 3 levels of success, thus defining a 6 x 3 rubric for assessing future PST ability to design experiments. Dimensions assessed in this rubric are: (i) Hypothesis formulation, (ii) Criterion of hypothesis verification, (iii) Dependent & independent variable identification, (iv) Control of variables strategy implementation, (v) Necessary materials & devices indication, (vi) Experimentation & data collection process description. Each one of the aforementioned dimensions is assigned 3 levels of success and awarded 1 to 3 points respectively. The total score of each learner can be calculated by summing the points from all dimensions (max 6x3=18). A specially constructed worksheet is used for prompting learners' answers in each dimension. This worksheet works both as a scaffold for learners' designs and at the same time facilitates the assessment of the design of experiments.
As an example, the levels of success for the dimension of hypothesis formulation are displayed in Table 1. Since the original scheme [9] was proposed for younger learners, these levels were adjusted to better fit the PST levels of success, enhancing the rubric's granularity, using a content analysis approach on their answers.
In a pilot study the designs of experiment of 35 future PST, were assessed at the beginning of the semester. Using this rubric, we were able to probe their difficulties in some dimensions, like the hypothesis formulation or the manipulation of variables, as also reported elsewhere [5].
Table 1 The levels of success for the Hypothesis formulation

Success Level Dimension: Hypothesis formulation Points
Level-1 Learner formulates a hypothesis based on alternative conceptions or incorrect assumptions 1
Level-2 Learner formulates a hypothesis based on scientifically accepted assumptions 2
Level-3 Learner formulates a hypothesis based on scientifically accepted assumptions, also using scientific terminology 3
3 Conclusion
Designing an experiment is an important stage in experimentation and future PST should be trained to acquire this ability. In this work, we have proposed a rubric for the assessment of the ability to design experiments in 6 dimensions, to be applied using a specially constructed worksheet for a paper & pencil task. Using this scheme we were able to identify difficulties in some dimensions. This kind of task and assessment scheme can be used for monitoring the development of the learners' ability to design experiments. Moreover, it can easily be implemented even in large audiences, in f2f or distance education, since no laboratory equipment is used.

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Parallel 1 - Wroclaw / 70

The Influence of Traditional and Digital Homework on Students' Academic Performance and Attitude towards Physics

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Abstract. Due to the advances in digital technology, many new perspectives have been opened in the educational system. Due to the COVID-19, the educational systems had to change perspectives of teaching and the teaching environment has changed, too. This study discusses the effect of digitalized education on students' academic performance, cognitive development and long-term information processes, and investigates the role of handwriting in education – focused on the homework solving – and compares it with the opportunities given by using digital methods.
1 Introduction
Nowadays, the traditional handwriting-based education has partially been replaced by a digitised way of teaching, as the use of digital technology is popular in education. Our students are members of the Generation Z [1], they find the out-of-classroom digital environment natural. They have grown up in a world, which offered them rapidly changing and powerful impulses, thus they have shortened concentration span and reduced single focus attention [1]. Most of the students find traditional, paper-based education less appealing, while there is a strong need for digital teaching. Is handwriting still important? Why is it necessary to rely on digital technology in education? We seek to answer these questions based on the results of literature review and our own investigation.
2 Objectives and research questions
In this paper, we investigate the role of traditional, paper-based and digital teaching methods in education. Our research focuses on the advantages and disadvantages of handwriting, as well as how it contributes to the development of cognitive skills. The study concentrates on the field of Physics education, and investigates the opportunities offered by the digital environment to Physics teachers. The investigation focuses on solving homework assignments with different methods – in the paper-based and in the digital way. We observe the influence of handwriting-based and digital homework solving on students' academic performance, and investigate which methods allow for the acquisition of long-lasting, solid knowledge. We organised our investigation based on the following research questions:
1. What are the effects of traditional handwriting-based teaching and learning methods on the development of cognitive skills?
2. Why and to what extent is it necessary to digitize education, to use digital tools in the Physics lessons?
3. Is digital homework more effective than traditional handwriting-based homework?
With the results, we hope we could support colleagues in choosing appropriate methods for their students.
3 Research procedure – methods
After examining and critically evaluating literature in the role of handwriting-based education on the development of students' cognitive processes and comparing it with the opportunities of digitised education, we conducted a research to investigate the influence of the different methods on students' long-term information processes and their level of motivation among 26 7th graders in Budapest. We organised the students into two groups. Both groups had to prepare homework for each class. The test group completed digital homework – Google tests, multiple-choice questions –

while the control group solved paper-based homework. The tasks were completely identical. At the end of the unit, students took a post-test, and in order to examine the effect of the different methods on long-term memory they took a follow-up test two months later. The results were analysed with statistical methods [2]. To find out the opinion of students on the applied method, they filled in a questionnaire, they indicated their opinion on a 4 point Likert-scale.
4 Results
The results of the post-test of the two groups didn't indicate significant difference. On the other hand, there is a significant difference – decline – between students' post- and follow-up test results in the digital group, but there is no significant change in time in the academic performance of students who did homework with the handwriting-based method.
The results of the questionnaire indicated that homework-solving is not motivating, even if it is digital, but all of the students from the test group found the digital way of work interesting. Students from the control group stated that the traditional method helped them achieving good academic results.
5 Conclusion
In our study, we compared the traditional paper-based and digital teaching and learning processes. We investigated the difference between the effect of traditional and digital homework solving methods on students' school performance and their attitude towards learning Physics. Our students seem to have a similar attitude to both methods. The results of our research indicated that digitally acquired long-term knowledge was significantly poorer than knowledge acquired through paper-based methods. The results of our investigation contribute to the further investigations and development of digital Physics teaching methods.

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Parallel 4 - Wroclaw / 71

Interdisciplinary approach to Quantum Technologies: a teaching - learning experience for high school students

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Quantum Technologies will have fundamental social and economical implications in
the next future. Therefore is urgent to make new generations aware of disruptive potential of these technologies so they can fell part of the second quantum revolution. Using an interdisciplinary approach, we designed and implemented a teaching learning sequence for high school students about the core concepts of quantum physics and the tenets of quantum computation. The intertwining between logic and physics enables students to understand the new way quantum computers manipulate information. In this paper, we present the design principles
and the encouraging results of its implementation.

Parallel 5 - Wroclaw/Guayaquil / 72

Reasoning processes in mathematics education and its connection to natural sciences – A theoretical paper

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In this presentation, school mathematics is interpreted as empirical theories with the help of scientific structuralism. The focus is on reasoning processes that show similarities to reasoning in the natural sciences. This is discussed on the basis of theoretical considerations and explicated by means of a mathematics textbook example.

Parallel 8 - Wroclaw/Guayaquil / 73

Using Virtual Reality for Teaching Kinematics

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Simulations have been used for decades to teach physics concepts. Virtual Reality (VR) opens new avenues: the benefits of acting out physis (embodiment) can be combined with the affordances of a simulated environment. This paper aims to demonstrate how to create physics-education simulations in VR with minimal effort, using the Unity game development environment in connection with consumer-grade VR gear.

Parallel 1 - Wroclaw / 74

Games for Quantum Physics Education

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Symposium
Games for Quantum Physics Education
Responsible
Marilù CHIOFALO
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Introduction
Educating to quantum physics is becoming a priority as an extraordinary opportunity to educate

physics intuition and innovate physics teaching, and to build up awareness on quantum technologies while they revolutionize our lives. We have no direct experience of the microscopic phenomena underlying the world we have experience of, and so beautifully explained by quantum mechanics with its advanced formal machinery. Thus, we cannot easily rely on experience nor math to educate our quantum-physics intuition. In this Symposium, we propose that games may provide a playground with engaging forms of experimental and symbolic literacy at everyone's reach. We explore the extent which this idea can be effective to, with scientists who pioneered it.
According to estimates, by the age of 21 the average US citizen has spent playing videogames the equivalent of a 40 hours/week full-time job for five years [1]. People have started to wonder if this enormous amount of human brainpower can be harnessed for tasks beyond the grasp of current computer machines. One answer is by designing games with a purpose (GWAPs). Citizen science has become a powerful approach in research, educational, and decision-making contexts [2,3]: games have goals focused on in epic, emotions activating, adventures, a set of rules that are constraints but also opportunities unleashing creative thinking to cross skill limits, a feedback reinforcing motivations, a voluntary participation allowing to leave or keep up while not dreading failures. In fact, games are extraordinary tools in pedagogy [4] to develop competences [5] and foster community building: in fact, a non-perishable and yet untapped source of extremely valuable goods in terms of problem solving.
Despite these ideas might sound extravagant, there are many successful examples of GWAPs for research problems [6] starting from the seminal Foldit experience down to proposals to integrate human and machine minds to solve otherwise intractable quantum problems [7], and for education in classical and quantum physics pioneered by the contributors to this Symposium within ScienceAtHome, QPlayLearn, QWorld, and Quantum Game Jams [8], leading also to creating a GTG on the topic within GIREP, coordinated by the Symposium responsible. "Creating the learning ecosystem necessary to inform and educate society about quantum technologies" enabling "the emergence of a quantum-ready workforce" [9] has more recently been growing as a goal, cross-disciplinary boosted within the European Quantum Flagship Coordination and Support Action for Quantum Technology Education, which all the Symposium contributors are involved in, with Jacob Sherson the QTEdu coordinator, and Marilù Chiofalo and Zeki Seskir coordinating the pilot QuTE4E on outreach and education.
We believe that WCPE represents a timely spacetime to dig into the topic in a systematic, critical, and rigorous manner, unveil opportunities and criticalities, elaborate under theoretical and practical perspective the specific physics-education research tools.
The Symposium addresses a number of fundamental questions. Sabrina Maniscalco first elaborates on the delicate question of whether and how the use of quantum games as educational tools can be framed into a global and strategic vision to root a durable educational and societal change. What is a quantum game, what makes any game 'quantum', and how quantum games effectiveness for education can be assessed are the questions posited by Zeki Seskir. How humans think about quantum mechanics regardless of their educational level and used game form is the dimension explored by Jacob Sherson, also illuminating potential and practical implications in increasing players knowledge of quantum research and technology in society. Down to which age one can design effective games for quantum physics education, is the dimension explored by Cristina Lazzeroni with her class-workshop experience of proven impact record, incorporating arts and crafts and creativity to convey a scientific and inspirational message on particle physics in primary schools. With her renowned expertise, our Discussant Marisa Michelini, GIREP's President, can lead the discussion, bridging the panelists diverse stories and channelling them into crucial methodological and practical aspects.
Given the leading roles of the participants to this field, the Symposium will also offer a wide-open vision of status and perspectives, discussing in depth and width the challenge of building up an ecosystem on quantum science and technology education.

Description of presenters:
1) Professor Sabrina MANISCALCO, QTF Centre of Excellence, Department of Physics, Faculty of Science, University of Helsinki (Finland), CEO of Algorithmiq Oy, Creator of QPlayLearn
2) Professor Zeki SESKIR, METU Physics Department, Ankara (Turkey), Co-founder of QWorld, Co-coordinator of the pilot QuTE4E within QuTEdu of the European Quantum Flagship
3) Professor Jacob SHERSON, School of Business and Social Sciences, Aarhus University (Denmark), Director and founder www.ScienceAtHome.org, Coordinator of QuTEdu CSA
4) Professor Cristina LAZZERONI, University of Birmingham Edgbaston, Birmingham B15 2TT (UK), Spokesperson of NA62 at CERN, Creator of Particle Physics for Primary Schools Education

Discussant

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Quantum Games as Tools in a Strategic Educational Vision: the experience of QPlayLearn

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Abstract. Educating to quantum physics is an inevitable must, while quantum technologies revolutionize our lives. But quantum mechanics is one most counterintuitive theory, manifesting in a reality we have no direct experience of, and represented by tough formalisms. Games can provide a playground for engaging forms of experimental and symbolic literacy at everyone's reach. Here we present the global educational strategy and vision that we have implemented in QPlayLearn, to provide multilevel education on quantum science and technologies for anyone, where serious games are essential toolbox items. We report on the ongoing assessment of its potential and effectiveness, performed by physics education tools.

1 The context

Teaching quantum physics to school students and the general public represents an inevitable must, while quantum technologies revolutionize our lives. Quantum literacy is a formidable challenge and opportunity for a massive cultural uplift, where citizens learn how to engender creativity and practice a new way of thinking, essential for smart community building. Scientific thinking hinges on analysing facts and creating understanding, then formulating these with dense mathematical language for later fact checking. Within classical physics, learners' intuition can be educated via classroom demonstrations of everyday life phenomena. Their understanding can even be framed with the mathematics suited to their instruction degree. For quantum physics instead, we have no experience of quantum phenomena, and the required mathematics is beyond non-expert reach. In fact, quantum mechanics is known as one the most counterintuitive and bizarre physical theories, involves imagination and diverse thinking, and a change in paradigm perhaps more radical than any

other in the history of human thought: quoting Niels Bohr “Anyone who is not shocked by quantum theory has not understood it”. Therefore, educating everyone’s intuition in quantum physics needs alternative forms of experimental and mathematical literacy: educators would otherwise face the risk of providing only evanescent tales, often misled, while resorting to familiar analogies.
In this context, games designed with a purpose can be effective tools for the general goal of innovating educational processes and the specific (here crucial) goal of providing a playground for physics concepts that cannot be easily experimented with everyday-life experience. Games are exceedingly more challenged than reality: players are engaged to overcome their limits and rewarded by skill challenges, which implies to amplify motivations and unleash creative thinking as ever-lasting resources for community development [1,2]. But hinging on games as educational tools without a global vision of the educational frame, may easily fail to produce a real cultural change we aim at, and root it into a durable educational and societal transformation.

2 The QPlayLearn vision

Here, we report on the global strategic vision that we have implemented in QPlayLearn [3,4], an online platform conceived to explicitly address challenges and opportunities of massive quantum literacy. QPlayLearn was born from a group of scientists passionated about quantum science and firmly believing that everyone can learn about quantum physics and its applications. QPlayLearn’s mission is to provide multilevel education on quantum science and technologies to anyone, regardless of age and background. To this aim, interactive tools enhance the learning process effectiveness, fun, and accessibility, while remaining grounded with scientific rigour. As a strategy for massive cultural change, QPlayLearn offers diversified content for different target groups, from primary school all the way to university physics students, to quantum science enthusiasts. It is also addressed to companies interested in the emergent quantum industry, journalists, and policy makers needing to grasp what quantum technologies are about.
Inspiring to the theory of multiple intelligences [5], QPlayLearn’s holistic perspective stems from the recognition that different types of intelligence dominate the learning process of each person. Therefore, the platform is conceived to accompany users in the travel through Alice’s rabbit’s hole via different paths aimed at: 1) building intuition and engagement through games and videos; 2) understanding physical concepts through accessible and scientifically accurate descriptions, graphics, animations and experiments; 3) acquiring formal understanding through the mathematics. For each concept in the dictionary, each user can begin from the approach that feels easier to him/her, and then possibly explore the others. Eventually, it is the combination of the different manners that shifts and expands the understanding of quantum physics.
In this context, games are one of the tools, embodied in the section Play, to stimulate the interactive participation of the users to grasp the counterintuitive features of quantum physics. Besides games, short animations (Quantum Pills) explain concepts at different understanding depths, useful for experts and not. In the Discover section, experts explain concepts with short videos, using metaphors, experiments or deductive examples. The Learn section enters the formal core of the quantum theory, devoted to a more expert audience. In the Apply section, concepts can be practiced by running code samples on real-world quantum devices. Finally, the Imagine section offers an environment totally free from restrictions, where learning proceeds via the preferred user’s artistic language, in fact involving creativity at its most.
After presenting QPlayLearn, we will report on ongoing investigation of its potential by means physics education research tools, to assess how to fully exploit its opportunities and transform its possible limitations in learning and teaching processes.

3 Conclusions and perspectives

QPlayLearn is a free platform for wide and diverse use, intended to tailor education processes on quantum science on the many talents of different users, operate a diffuse and massive cultural change, build up literacy and awareness. Because of this flexibility, QPlayLearn can be adopted by educators as largely as one can imagine at first.
While we proceed in the goal of assessing the effectiveness of our approach, we are working to different perspectives, such as completing the quest environments, adding a multiple language version, and extending the class of beneficiaries to 0-99 years old users together with pedagogy experts. This is, we believe, an authentic priority and in fact also a unprecedented challenge.

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Theorizing Quantum Games for Education

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Abstract. Quantum technologies have been becoming increasingly an important topic for education research. Quantum games possess the potential to become a general tool for increasing both awareness and literacy in quantum technologies and to attract new audiences to the field. In this work, we would like to explore the existing landscape of quantum games and posit certain questions that we believe can help researchers who wish to study them on both conceptual and practical levels.

Quantum technologies have been becoming increasingly an important topic for education research, especially as new M.Sc. and B.Sc. level education programs for Quantum Information Science and Quantum Engineering are coming to life in the US, the EU, and China.
Although, the topic of how to best present quantum phenomena related to the second quantum revolution in the context of education has been discussed previously in the literature [1,2] more recent discussions heavily focus on quantum technologies, computing in particular [3,4,5]. This is not surprising considering that the literature in quantum technologies has grown nearly three orders of magnitude in the last two decades [6], and quantum computing has been receiving particular attention with developments like the demonstration of 'quantum supremacy'[7], a term used for denoting the point where a quantum computer performs much better at a task than the best available classical computer, regardless of whether that task is useful or not.
In this context, quantum games have been proposed as a medium where people can learn quantum computing without many previous requirements [8], and an experimental environment for introducing learners to quantum mechanics [9]. It has been noted that allowing scientific experimentation is an important part of fostering scientific inquiry [10], and in the quantum realm, such experimentation opportunities are not readily available for the majority of the population. Hence, properly designed games [11] can be used to close this gap to some extent.
We believe that quantum games allow the easiest approximation of experimentation in a quantum regime. Players interacting with games constructed upon 'classical' game engines reinforce their intuitions on how the 'classical' world operates, a similar approach can be adopted for quantum games and the quantum world. Therefore, it is important to explore which aspects, actions, engine properties, and integration methods are most effective for building up players' intuitions.
We have found that there are more than 100 'quantum games' that have been developed around the globe, and most of them are freely accessible. Existence of such games, with the increased presence of global online communities (due to COVID-19), we believe that this is an opportune moment to explore the possibilities provided by utilizing quantum games for education and outreach purposes within the second quantum revolution.
The phenomenon of the digital divide [12,13] is expected to translate into the quantum era, where similar to the severe inequalities in access and utilization of digital technologies, there will be even further inequalities in access and utilization of quantum technologies. There are several initiatives trying to gap this divide early on, however, developing high-quality quantum games that foster scientific inquiry, and raise quantum literacy would bolster these efforts significantly.
In this context, we would like to posit and try to develop the following questions:
- What is a quantum game, what makes any game 'quantum'?
- Can there be a 'quantization method' of classical games, which turns regular games into quantum games?
- Can we assess the effectiveness of different quantum games with the same assessment tools, and if so, how can these assessment tools be developed?

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Playing Games with Quantum Physics

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Abstract. Amidst the second quantum revolution, there is an increasing need to educate people, both students and the general public. Games provide a unique platform for this, as they can engage these populations and allow them to learn about quantum mechanics in a playful setting. Citizen science games are also extremely interesting in that they can combine the educational efforts with research efforts. Here, we describe some of our efforts in gamifying quantum citizen science, especially as they relate to the use of human common sense in finding solutions to quantum problems.

1 Introduction

Amidst the second quantum revolution, where quantum technologies and solutions are being developed for sensing, simulation, computing, and networking purposes, there is the potential for incredible economic development, but this also comes with potential societal impacts. As such, there is an incredible need to educate students and the general public about quantum technologies, their benefits, and their potential drawbacks. That is, there is a need for an increased quantum literacy among the public.

Games are a unique way to approach this problem. A game can be interesting and engaging for people across a wide range of backgrounds and disciplines, and educational material can then be developed about the topics considered in the game, helping to build the desired competences. In addition, citizen science efforts are useful in that they engage the general public in research projects, fostering interest and a desire to help further scientific knowledge.

At ScienceAtHome, we have developed a number of quantum games and initiatives aimed at building quantum awareness and quantum literacy, and some of these games include citizen-science-based tasks where players contribute to cutting-edge quantum research. In particular, we are interested in understanding how amateurs and experts approach and solve quantum problems, tapping, in some sense, into human intuition about a very unintuitive subject. In this proposal, we outline briefly some of our games and their relevance for quantum education and research. We conclude by discussing the potential for such games in the future.

Fig. 1 Screenshots of Quantum Moves 2 (left) and the Quantum Mønster (right)

2 Quantum games and initiatives

In this section, we will describe some of the quantum games and initiatives developed by ScienceAtHome; all games and surrounding educational material can be found online [1]. In Quantum Moves 2 (QM2, Fig. 1 left), the player is tasked with solving relevant problems in the control of a quantum

state consisting of one or many atoms, and the quantum state is represented as a liquid-like object that sloshes around as the player manipulates the system in which it resides. We have found that player solutions can provide valuable information to researchers [2], even in the face of the unintuitive nature of quantum mechanics, and QM2 has been used in numerous educational scenarios, including a randomized control trial on research games in Danish schools [3], where students play QM2 and learn about physics.
The Quantum Mønster (Fig 1 right, Danish for "pattern") is being developed to help physicists understand the theories underlying the behavior of electrons in ordered potentials, which is useful for the study of high-temperature superconductivity. As with QM2, the Quantum Mønster is aimed at understanding how amateurs and experts think about the problem at-hand, with the goal of helping neural networks to better classify these theories.
The same is true of the Netty game, where players are tasked with helping to solve problems regarding the organization of quantum spins in networks; the minimization of the energy of the system is an NP-hard task for classical computers. We also developed the Rydbergator, a gamified tool used for understanding how interacting atoms organize themselves in the presence of highly-excited Rydberg states. Finally, in 2018, we opened up our laboratory to the general public for the Alice challenge, wherein citizen scientists used a gamified interface to optimise the cooling of atom clouds used for quantum simulation experiments; the amateurs were able to make larger clouds than the experimental experts had previously [4].
Thus, games like these are useful for scaffolding both self-reflection and quantum knowledge—in each case, we have developed a unique visual interface and means of interacting with the system. This allows us to both tap into what makes human thinking unique and educate the public via their participation in scientific projects.

3 Conclusion

While quantum games can take many forms, from games developed using quantum computers to purely educational games aimed at teaching the player something about quantum mechanics, the suite of games developed by ScienceAtHome are aimed at exploring how humans think about quantum mechanics regardless of their educational level in physics. In addition, we seek to educate our players on the relevant aspects of quantum mechanics applied in the games they play, increasing knowledge of quantum research and technology in society.

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Particle Physics for Primary Schools Education

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Abstract. Particle Physics for Primary Schools (PPPS) is a project born in UK in 2016 to bring the excitement of modern physics and the particle world to primary school children. PPPS was devised as a pioneering collaboration between University of Birmingham researchers, a local school teacher and the Odgen Trust. Originally developed as an iterative process involving testing sessions in local schools, after many years PPPS has reached a large national audience and a proven record of impact. A class workshop is the main element, incorporating arts and crafts and creativity, to convey a message that is both scientific and inspirational.

The rapid change in science and technology witnessed in the last decades have significantly increased the awareness in decision makers and education stakeholders of the need to strengthen the connection between outreach and research and education. he accent has rapidly moved from "outreach" to "engagement", in order to reflect the need of a two-ways-processes where contributions and benefits are present for all parties. In this context, the project to divulge particle physics research concepts to primary school children represents a fruitful example of a collaboration between academia, school teachers and professional outreach officers.
The project stems from the mounting evidence that early school years are critical for children education, and are influential for the later development, including personal attitude towards science and its perception. The project finds its rationale in the compelling need to modernise the science con-

tent of both primary and secondary schools, taking modern 20th-century physics to the classroom, with its fundamental questions, its fascination and inspiring wonder.
The common perception of 18th century classical physics as a set of well-established concepts doesn't help to raise the interest of young minds towards science; most importantly it doesn't foster or promote the message that science is a dynamic process to which individual children can directly contribute once adults. This message is however essential to establish a personal connection between children and science and a sense of ownership of the subject, and ultimately to increase the society science capital.
The project was developed as part of a school activity. The main aspect of the project is a workshop, led by researchers and/or teachers, to be performed during class lessons or as an after-school club. The workshop is complemented by enrichment and feedback activities. The project also includes an aspect of teachers training and continuous development.
The workshop starts with an introduction to the world of elementary particles, with practical demonstrations of key concepts to promote children active participation. The introduction is followed by a range of creative enjoyable activities, with an increasing degree of complexity and physics content. The activities range from making models of elementary particles inspired by their characteristics (such as mass, electric charge, and particle families), to card games to facilitate the assimilation and consolidation of notions and concepts. The games explore more challenging concept relating to the quantum world, such as particle interactions, matter-antimatter annihilation, and the beauty of Feynman diagrams. The gaming aspect has been identified as key to facilitate the learning process of young children.
The workshop includes both single and group activities. The workshop concludes with a group activity that sees children explaining and demonstrating their work and creations to fellow students and teachers; this part facilitates and promotes the communication aspect of the project, while allowing checks of the learnt concepts and ideas.
The project has been recently extended to schools in Greece and in Italy. The art-and-craft aspects of the workshop are crucial to transmit the message there isn't a rigid dichotomy between art and science, and that creativity is in fact an essential part of the scientific process. Particular emphasis has been placed on the need to divulge a correct and detailed scientific message, albeit simplified and tailored to the audience using metaphors and similitudes. Finally special care has been taken to avoid limiting the freedom of creative expression, allowing children to use their favorite art media (that being drama, dance, poetry, narrative, illustration etc.) for most of the activities.
The follow-up enrichment activities have been left to the teachers with suggestions from the researchers, to explore connections between physics and other sciences, and between science and other disciplines. As an example, the aspect of citizenship in science can be addressed when speaking of international science collaborations that are natural in experimental particle physics research.
The aspect of teachers and ambassadors training have been developed over the years, to make the project scalable and sustainable, with the help and collaboration of several scientific institutions such as the Institute of Physics, the Ogden Trust and the STEM Ambassadors. Resources have been developed to this end, consisting of a teacher manual and educational material to assist the delivery of the workshop. As a result, a sizeable number (in the hundreds) of primary teachers have been successfully trained to deliver the workshop in England.
The impact of the project has been verified collecting feedback from students and teachers before, during and one month after the project. As well as measures of how enjoyable the project was, indicators of specific impact, such as quantity and quality of scientific content assimilated and remembered, and changes in behaviour, attitude and perception towards science have been recorded. The results are positive, indicating a clear evidence of a positive impact on students.

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Environmental Thematic in Brazilian journals of Physics Education and Environmental Education

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Abstract: *What kind of articulations between physics and environmental theme can be identified in some papers published in Brazilian journals on Physics Education and Environmental Education? The investigation was qualitative and bibliographical and aimed to understand the Brazilian knowledge produced by researchers who seek to build bridges between Physics Education and Environmental Education. The research was based on Analysis Content procedures. The data indicate a more critical perspective on the environmental issue and pedagogical perspectives aimed at building citizenship and a process of questioning socio-environmental injustices. This information contributes to outline an overview of Environmental approaches in Physics Teaching.*

1.Introduction

Environmental issues present many important challenges for our society. Some environmentalists indicate that there is an environmental crisis [1]. In Brazil, the field of science education has been a kind of gateway to the presentation of environmental issues for students from 6 to 17 years old [2]. Although, traditionally, the discussion of environmental issues has turned more often to ecological issues. However, other fields of science may contemplate other dimensions of environmental issues. Physics, for example, is essential to understanding complex problems such as global warming [3].

In this context, there are few articles relating Physics Education and Environmental Education [4,5,6]. According to [4], this small number of articles may be associated with the fact that the Teaching of Physics, for many years in Brazil, has focused on considerations specifically aimed at teaching specific contents of Physics. However, the number of articles that are focused in Environmental Education and Physics Education has increased significantly since the 2000s. Most of them present the links between environmental issues and social injustices [4,5].

Seeking to contribute to outline a panoramic perspective of the connections between Physics Education and Environmental Education in the Brazilian context, a question was elaborated: what kind of articulations between physics and environmental theme can be identified in some papers published in Brazilian journals on Physics Education and Environmental Education?

Four Brazilian journals were chosen to this investigation. The Revista Brasileira de Ensino de Física and the Caderno Brasileiro de Ensino de Física are associated with physics education. The Revista Brasileira de Educação Ambiental and the Revista Pesquisa em Educação Ambiental are associated with Environmental Education. The documentary corpus was constituted by searching for articles in electronic address of these four journals. Two terms were chosen for this search: environment and physics. From 3,383 articles, 23 were chosen at this stage of the research.

The researcher have read the 23 articles. After reading the articles, 14 articles were chosen to compose the documentary corpus of the research. All these 14 articles bring a discussion that articulates the environmental theme and the physics education. Content analysis [7] techniques were used for the analysis. Excerpts with relevant content for this investigation were found in the articles and then organized into groups according to the similarities of ideas and named by a unit of meaning that converges to broader categories.

2.Findings

2.1 Environmental Thematic understands

Two categories were named. The first is the Social Dimension of the Environmental Theme and the second the Complexities, Controversies and Uncertainties of the Environmental Theme. These categories include ideas related to the anthropogenic and cultural influence on the intensification of environmental issues, criticisms of the American way of life, considerations about the implications of environmental problems for human life and the importance of the media for the massive understanding of environmental issues. Considerations about the complexities, controversies and uncertainties intrinsic to environmental issues were found.

2.2. Articulations between Environmental Thematic and Physics Education

Five pedagogical strategies were identified to articulated contents of Physics and environmental themes: 1) Approaches based on Environmental Education; 2) Contextualization perspective from social and environmental themes; 3) Science, Technology, Society and Environmental (STS/STSE) education; 4) Interdisciplinary and 5) Scientific and Technological Leaning.

3. Conclusion

There is in these articles a more critical perspective on the environmental theme. These articles also contain considerations on citizenship and social justice. It is important to expand studies like this to theses, dissertations and other articles from other journals. Building an overview of environmental issues in the literature on Physics Education can indicate significant perspectives for the area and guide teaching practice.

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Parallel 7 - Wroclaw / 76

Acceptance of Dirac-Notation by high school students

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Quantum physics recently gains greatly in attention in school education. The central question is to which extent it can, cannot or even has to be taught with formal mathematical means. In the context of two-state-approaches the use of Dirac-notation seems an adequate possibility. Therefore we present an approach for high school using Dirac-Notation that was applied in an exploratory study analysing the acceptance of Dirac-notation by high school students. This study gives promising results if the some basic mathematics skills are properly addressed.

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A FRAMEWORK FOR DESCRIBING LEARNERS' MENTAL MODELS OF QUANTUM PHYSICS CONCEPTS

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In this contribution, we report on a questionnaire study conducted with 280 physics students into learners' mental models in QP in order to uncover the mental models' theoretical dimensions. Therefore, an established questionnaire on students' mental models on QP from literature was adopted. A principal component analysis of the survey data led to two independent dimensions describing the participants' mental models in QP, namely Fidelity of Gestalt and Functional Fidelity. Based on these results, we discuss a theoretical framework of mental models in QP against previous empirical studies from quantum physics education and derive implications for physics teacher education on QP.

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Improving women motivation in learning Physics

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We want to analyze the motivations in the study of physics in pre-university educational levels. 69 undergraduate students who learnt with a Brain-Based Teaching Approach (BBTA) methodology (Socratic style) were compared to a sample with the same N who had learnt in a masterclass style. Both groups where analysed through Academic Motivation Scale (AMS). T-test and U Mann-Whitney analysis suggest amotivation is the same in both groups, but extrinsic motivations are higher in the classic style group, while the intrinsic motivations are higher in the Socratic one, specially for women ($p<0{,}032$). To learn Physics in the proposed way seems to reinforce intrinsic motivations.

Parallel 6 - Hanoi / 83

A mathematical model of peer-instruction including stochastic uncertainty

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As a class of statistical transition processes, a mathematical model of peer-instruction including stochastic uncertainty is presented. Expectation and variance are shown by using direct numerical simulations of the resultant model and moment equations with a simple closure. The resultant model will provide insights to the real data beyond the standard statistical analysis.

Parallel 5 - Wroclaw/Guayaquil / 84

International Particle Physics Outreach Group: Engaging the world with science

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Abstract. The International Particle Physics Outreach Group (IPPOG) is a global network of researchers, educators and communication specialists working together to develop and share best practices in science education and public engagement. Our major activities include organisation of International Particle Physics Masterclasses and the Global Cosmics portal, promotion of International Muon Week and International Cosmic Day, and participation in activities ranging from public talks, festivals, exhibitions, teacher training, student competitions and open days at local institutions. These independent activities, often carried out in a variety of languages to public with a variety of backgrounds, all serve to gain the public trust and to improve worldwide understanding and support of science.

Parallel 7 - Wroclaw / 85

Films and Newtonian laws. A brain tool for learning Physics.

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69 undergraduate students who learnt with a Brain-Based Teaching Approach (BBTA) methodology, versus a master class teaching method, has shown some advantages in reasoning processes and higher motivations. We want to show an example of application of this method.

Parallel 9 - Hanoi / 86

Consideration of nature of science in a modern physics course

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This study sought to determine whether adding nature of science to the physical content of modern physics course could help the undergraduate students to promote their scientific worldview and physical knowledge. Experimental and control groups of physics education students were provided with pre-exam and post-exam sheets and were interviewed after passing the course. The responses of students and interviews were analyzed qualitatively. It was concluded that learning modern physics totally changes the perspective of both groups about science considerably but the experimental group shows more promotion on their scientific worldview and physical knowledge.

Parallel 1 - Wroclaw / 87

2Q-System: A Tool for Lesson Planning and Continuous Monitoring of In-Lesson Learning Progress

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We developed a system based on a series of two multiple-choice questions (2Q-system) used for diagnostics of students knowledge at the beginning of physics exercise classes and to continuously monitor the learning progress during the course. The system was successfully implemented at ETH Zurich for selected introductory and advanced physics courses. With the 2Q-system we were able to measure learning gains of more than 25 % in almost all lessons.

Parallel 3 - Hanoi / 88

Snapshot on student voices in COVID-19 physics labs

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Abstract. This study explores how students engaged in experimental labs which were not designed for online delivery but were transferred online due to COVID-19. This created an interesting opportunity to measure the impact of online instruction, notably in somewhat stressful conditions. Data were collected in semester one of 2020 from first-year undergraduate students at two universities in Australia. We highlight student engagement using the two-factor theory of motivations in the shifted online labs.

1 Background and Context

Experiments designed using conceptual frameworks have shown better student engagement [1]. National wide projects have been focused on evidence-based research to improve undergraduate experiments and found that students' experiences are related to the two-factor theory of motivations 'experiment-based motivators' and 'course-level resources' [2]. Considering the fact that the labs are not designed for online delivery, this study focused on undergraduate lab programs with the following research aim:

Aim: To explore student engagement in undergraduate science labs in two universities.

2 Method

This study has been conducted at two large, research-intensive universities in Australia: The University of Sydney and The University of Melbourne. A survey focusing on students' engagement following approved Human Ethics protocols was administered at the end of the lab programs. There were 735 participants in total who responded to one open-ended question. The university names were deidentified to Uni X, Uni Y, and the samples are shown below in the table1.

Table 1: Sample sizes of first-year physics labs from two universities.

University	Uni X	Uni Y	Total
Participants	n=612	n=123	N= 735

3 Analysis & Results
The open-ended question, "What aspects of the experiments did you find most enjoyable and interesting?" was analyzed using thematic coding. Three researchers were involved in the coding to ensure correct interpretation was made with respect to lab delivery, as well as for validating the emerging themes. First, the primary researcher went through each response and identified the emerging themes, and validated with the other two researchers. The final themes were then aligned to two factors from the survey analysis, as listed in Table 2.

Table 2: Description of themes, quotes, and results from the thematic coding of student voices

Experiment-based motivators Course-level resources
Themes:
• Planning & Conducting, Hands-on
• Data Collection, Data Analysis, Data Interpretation
• Prediction, Understanding Physics, Physics Relevance, Writing Report Themes:
• Demonstrator's Help, Teamwork
• Technology
• Experimental Procedure, Background Information
Quotes:
• I found analyzing the data is very enjoyable
• The most fun is when you design experiments.
• Comparing the results to theory and how they correlate. Quotes:
• Using excel to use functions and graphs
• I found doing them in groups to be good.
• When seeing clear and helpful instructions.

4 Discussion
The results highlighted interesting and engaging aspects of the lab programs and the features that were retained during the online delivery. Despite the differences shown between the universities, students were more motivated from Hands-on experiences such as designing the experiments, data analysis which is not normally shown as an interesting aspect for them, and finding the relevance of the experiments to real life. Being online, students were required support from their peers and demonstrators showing that teamwork was more helpful. Having more background information and clear experimental instructions were helpful resources.

Acknowledgments

We thank all the participants and research groups who supported this study.

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Parallel 5 - Wroclaw/Guayaquil / 89

Engaging students emotionally with Physics using stories

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Engaging students emotionally with Physics using stories

Abstract. Incorporating stories though recommended to attract students, yet it is not implemented enough in undergraduate physics. We crafted novel colorful stories containing historical anecdotes to engage students emotionally. Stories on electricity practicals were created for two first-year physics courses, Environmental and Technological. Data were collected from 164 students, in the form of a survey, observations, and tutor interviews. Students from both courses scored their emotions on the survey. No significant difference was found between the emotions of the courses but correlations between emotions differed. Qualitative data points towards the differences in students' goals for the courses. Stories stimulated students' interests.

Introduction

Not all the students are interested to continue in physics. Stories can work as a vehicle for students' conceptual change, motivate them, develop various skills, and stimulate their imagination [1]. It seems likely that there will be inherent differences between how students Technological (TEC) and Environmental (ENV) feel about their physics courses. We incorporated stories in students' laboratory notes, measured using AEQ-PhysicsPrac [2] and compared students' emotions with two such courses and found interesting dynamics at work.

Method

Using AEQ-PhysicsPrac, we collected data from a total of 46 students from 62 present in ENV, and 118 from 187 present in TEC. Confirmatory factor analysis, descriptive statistics and inferential statistics were conducted on the quantitative data gathered. Thematic analysis was conducted on the qualitative data gathered through open ended questions on the survey.

Results

Being asked if they would like short colorful historical stories added to their laboratory instructions,, 60% answered 'yes' and 20% answered 'no'. Overall, it was found that students appreciated such a context given to their regular laboratory saying, 'They added context to the practical, they alloyed my resignation and left me in a better mood'. Students' responses could be reliably placed into seven descriptive categories as shown in table 1.

Catagories (Short form)
Example of students' comments
Interesting (I)
'refreshing', 'Yeah it is cool', 'sometimes motivated by the story'
Interesting and helps feelings (IF)
'It's good for my feelings about physics', 'It is always nice to hear about the greatness of Einstein-I idolise him'

Interesting and helps learning (IL) 'it provides another way of study', 'we can learn more things about the practical'
Interesting and helps feelings and learning (IFL) 'It was good to learn the history, somewhat helps create a direction of work and helps you get into the 'scientist' mindset'
Interesting but not helpful (IN) 'Interesting historical context, they didn't have any impact ... unless crucial knowledge for exams'
Uninteresting (U) 'Stories didn't motivate me. University is difficult. So is life'

Miscellaneous (M)
'Want this lab weighted more in the whole course', 'Perhaps the instructions in the manual to be clearer'

TABLE 1. Categories developed from students' open-ended responses

Table 2 below shows the Pearson's correlations; enjoyment and pride are correlated with each other for both courses, three of the four negative-valence emotions, anger, hopelessness, and boredom are correlated with each other. Anxiety is anomalous. In ENV, anxiety is correlated with enjoyment, but not with anger, while in TEC, anxiety is correlated with pride, enjoyment, and anger. Table 3 shows the descriptive statistics. The t-statistics with p > 0.05 for all the emotions, informed no significant differences between the two course.

Pr - .740**En .742** - .400**An - .702** .497**Anx .285** .250**.625** - .398**.325***
Ho .728 .652- **.683**
Bo .578**.292** .468-. Significant at the 0.01 level (2 tailed).
*. Significant at the 0.05 level (2-tailed).

TABLE 2. Correlations between the emotions for the ENV
(above the diag- onal) and TEC (below the diagonal)

Emotion Mean (SD;SEM) Range

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ENV (n=46)  TEC (n=117)
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Pr 14.20 (2.90; 0.43) 14.47 (2.49; 0.23) 4-20
En 16.78 (3.41; 0.50) 17.35 (3.80; 0.35) 5-25
An 8.15 (2.20; 0.32) 8.21 (2.43; 0.23) 3-15
Anx 7.87 (2.68; 0.40) 7.93 (2.89; 0.27) 3-15
Ho 5.30 (1.95; 0.29) 5.42 (1.94; 0.18) 2-10
Bo 5.48 (2.19; 0.32) 5.50 (2.06; 0.19) 2-10

TABLE 3. Comparative ratings for ENV and TEC for each emotion: descriptive statistics and t-statistics

Conclusion
The 'colorful historical stories' were well received for a series of experiments on electricity by students in the two courses, Environmental and Technological. Students responses pointed to the role of interest that links to attention, impacting engagement and learning. The quantitative measure of emotions are not significantly different for students in both the courses. I also looked into qualitative responses and it was visible that both the cohorts found the 'colorful historical stories' interesting. Though correlations between emotions are different for both the cohorts, TEC students having more correlations between the emotions and showcasing their anger/anxiety. This might be due to the fact that cohorts are different in their predilection for physics.

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Parallel 5 - Wroclaw/Guayaquil / 91

Pedagogical Considerations for Quantum Instruction

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We discuss developmental considerations for two quantum mechanics curricula: Paradigms in Physics (from Oregon State University) and Tutorials in Physics: Quantum Mechanics (from University of Washington).

Parallel 10 - Wroclaw / 92

Student Difficulties with the Propagation of a Pulse in a String

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This study explores students' difficulties with distinguishing between the horizontal motion of a pulse in a string and the vertical motion of points of the string. A conceptual questionnaire was initially designed and indicated several misconceptions students had about the topic. Based on the findings, three levels of scaffolding support to help students overcome these difficulties were provided. The result shows that scaffolding level 1 is less beneficial to the students. However, in scaffolding level 2 and 3, student performance gradually improved in different ways. We suggest that this is due to both prior knowledge and procedural competences of students.

Parallel 10 - Wroclaw / 93

Two simplified experiments for an estimation of surface tension

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Abstract. We present here two different experimental apparatuses for measures in the field of surface phenomena. Set-ups are low budget, using materials and experimental apparatuses available in ordinary didactic laboratories. The first one allows us to estimate the surface tension of soap bubbles and verify the Young – Laplace law. The second apparatus is a simplified version of the well-known Du Noüy ring and allows us to measure the surface tension of generic liquids.

1 Introduction
Although the comprehension of surface phenomena is relevant not only in physics but also in disciplines such as engineering, chemistry and biology, the traditional approaches used to introduce the basic concepts related to this topic often prove to be ineffective in fostering students' understanding. Consequently, it often becomes difficult to make this topic interesting for both high school and undergraduate students [1]. Our research aims to build and test alternative strategies to improve the teaching-learning process related to surface phenomena with a focus on surface tension, also introducing hands-on and minds-on experimental activities and interactive lessons based on active learning strategies. This approach may help to promote students' interest and authentic understanding of physical phenomena.
Here we present two different experiments to study and estimate surface tension. The equipment required for the experiments is readily accessible and very cheap.

2 The experiments
The first apparatus [2] allows us to measure surface tension of a soap bubble and verify the Young-Laplace law. A fundamental quantity is the overpressure Δp=p_int-p_ext inside a soap bubble, which is the difference between the pressure inside the bubble p_int and the pressure outside the bubble p_ext. This overpressure acts against the force due to surface tension γ of the soap film. In the case of a spherical bubble, the overpressure Δp can be obtained by the Young – Laplace equation
Δp=4γ/r (1)
where r is the radius of the soap bubble. The experimental apparatus allows us to measure both the overpressure and the radius, necessary to estimate del surface tension.
In the du Noüy ring method [3] one slowly lifts a metallic ring from the surface of a liquid. The force F required to raise the ring from the liquid's surface is related to the surface tension as follows
F=F_ring+4πRγ (2)
where F_ring is the weight of the ring and R is the inner radius of the ring. Thus, measuring F when the ring detaches from the liquid surface, we can determine γ.

3 Results and conclusions
The surface tension values obtained by using the two experimental set-ups are consistent with the results reported in the literature, but the experimental apparatuses cost only a fraction of the professional ones commonly available. Reconstructing and trialling experimental set-ups for educational

purposes by using inexpensive materials can be very important, as schools often do not have the budget needed to buy sophisticated, and often very expensive, professional laboratory equipment.
The experimental activities we propose here are part of a teaching/learning sequence. It also includes computer simulations and interactive lessons that will be trialled with a specific sample of high school students. Specific aspects of the teaching/learning sequence include students' active engagement in planning experiments, focus on important aspects of the observed phenomena and the use of models to predict results starting from testable hypotheses.

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Parallel 1 - Wroclaw / 94

Two Teaching/Learning Sequences on Surface Phenomena based on Minds-on Experiments and Model-Based Reasoning

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Abstract. In this contribution we present some preliminary results of the trial of two teaching/learning sequences on surface phenomena for High School students. The sequences have been trialled with a sample of students divided into two groups. The first follows a traditional approach, based on the macroscopic model of surface tension. The second involves the students in a more innovative approach based on a mesoscopic model implemented in Smooth Particle Hydrodynamics simulations. Both approaches are based on active learning methodologies and make use of minds-on experimental activities. We discuss the effectiveness of the two approaches in promoting student description and reasoning skills.
1 Introduction
The comprehension of surface phenomena is important not only in physics but also in other scientific and technical fields. The traditional methods used to introduce the basic concepts related to this topic are often based on an approach founded on macroscopic description and sometimes on interpretations involving molecular interactions. These methods often prove to be not very effective in captivating student interest [1] and in favouring students' authentic understanding of the physical content.
Educational research has shown that a change in teaching pedagogy from mainly deductive to methods based on active learning supported by minds-on experiments and modelling can provide the students with means to increase their interest in learning. Moreover, it has been shown [2] that implementing models in computer simulations can be a very useful tool for students. It can allow them to easily control parameters relevant for understanding the mechanism of functioning at the basis of the phenomena they want to study and greatly promote model-based reasoning.
Models built at an intermediate scale (i.e. mesoscopic scale) are recognized in the literature as useful to effectively introduce concepts like surface tension in educational contexts [3]. These models have the advantages of the microscopic one, but they do not require a lot of computational resources to successfully run the simulations implementing the models.
2 Research Aims
This contribution aims to first discuss the structure of two teaching/learning sequences (TLSs) on aspects of surface phenomena, both based on active learning and supported by minds-on and modelling activities. We want also to present some preliminary results of the trialling of the TLSs about the development of reasoning habits based on building mechanisms of functioning and explicative

models.
3 The Teaching/Learning Sequences
The Common aspect of both TLSs is the use of the "Predict – Observe – Compare - Explain" strategy in every phase, to facilitate the active and conscious participation of the students in building of knowledge.
However, one TLS is based on a purely macroscopic approach, focused on the description of the experimental results on the basis of forces acting at interfaces between media and energy. The second TLS relies on the introduction and computer implementation of a mesoscopic model of liquid. By using the simulation, the students can control some model parameters and compare the results of the simulations with the experimental results.

4 Conclusion
We first briefly introduce the general schema of the two teaching/learning sequences, highlighting their similarities and differences. Then, some relevant experimental and simulation activities are described. Finally, some preliminary results about the comparison of the learning outcomes of the two different teaching/learning approaches are presented.

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Parallel 7 - Wroclaw / 95

Computer-based simulation for a new educational approach to surface tension phenomena

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Abstract. An educational approach to the surface tension concept, founded on a novel mesoscopic model of liquid, is presented here. We discuss in some detail the mesoscopic model and show semi-quantitative results obtained by a computer simulation implemented through the Smoothed Particle Hydrodynamics method.

1 Introduction
The traditional educational approaches to surface phenomena are often based on a macroscopic description of forces acting at interfaces and, sometimes, on a microscopic interpretation. Besides being sometimes incorrect or inconsistent, both approaches often prove to be ineffective in captivating both high school and undergraduate students and fostering an authentic understanding of the physical content [1].
The general aim of our research is to build and test alternative strategies to improve the teaching-learning process related to surface phenomena, also by the use of a novel mesoscopic model of liquid. Models built at an intermediate scale (i.e. mesoscopic scale) are recognized in the literature as useful to effectively introduce concepts like surface tension in educational contexts [2]. These models have the advantages of the microscopic one, but they do not require a lot of computational resources to successfully run the simulations implementing the models. So, teachers/students can simulate large portions of liquids by using computers commonly available in school laboratories.
Here we present some computer simulation results of our mesoscopic model of liquid. The simulations have been designed so that students can manage them by simply controlling some relevant parameters of the model.

2 The model
In the mesoscopic model we present, the liquid is composed of particles whose size is much bigger than that of a molecule (particle radius can be equal to a fraction of a millimetre). The interaction forces acting between mesoscopic particles have the same properties as the forces between microscopic particles. They are attractive at large distances and repulsive at short distances. The value of this force depends on the two interacting particles (liquid-liquid or solid-liquid) and on the inter-particle distance.

3 Simulations results
At the equilibrium, the pressure inside a liquid droplet depends on the surface tension and droplet radius according to the Young-Laplace law. We simulate the formation of a two-dimensional liquid droplet without gravity and obtain its surface tension.
We also study the liquid capillarity as a function of the liquid-liquid and liquid-solid interaction intensity by simulating a liquid in a tray with a capillary tube inside. At the equilibrium, we observe the formation of menisci and the rise of liquid under the effect of gravity. The simulations results highlight the forces acting on the SPH particles and allow us to estimate the value of surface tension.

4 Discussion and conclusions
Simulative activities require high mindfulness of the students, and problem-solving and decision-making skills are fundamental to run the simulation. By step by step analysing how the parameters related to inter-particle interactions affect liquid behaviour, the students may have the opportunity to focus on the mechanism of functioning underlying the observed phenomena. Simulations ran and studied this way can help students to understand the importance of models building process and to learn how to use a model to predict results starting from testable hypotheses.
The simulation activities we designed are part of a teaching/learning sequence that also includes extensive hands-on and minds-on experimental activities and interactive lessons based on active learning strategies. We are planning to trial the sequence with a specific sample of high school students and accompanying teachers.

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Parallel 7 - Wroclaw / 96

The Schrödinger equation for a non-quantized matter field: a pedagogical introduction.

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Usual presentations of Physics Education start by postulating the existence of a classical field that obeys to the equation of motion, derived from a conveniently chosen Lagrangian density. But while electromagnetic fields are given a proper physics meaning, matter fields are considered only a technical instrument, unless they are quantized. Therefore, in this work, we aim to give a pedagogical construction which allows us to assign a physical meaning also to non-quantized matter fields. This operation is particularly important since we believe that Quantum Field Theory is more suited than Quantum Mechanics to introduce quantum physics in secondary schools.

Parallel 10 - Wroclaw / 97

Analysis of Smartphone Recorded Transit Light Curves via Astronomical Software

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Abstract. Exoplanet science is highly important in the understanding of the formation and evolution of planetary systems. In the last three decades extrasolar planet research has dramatically expanded and became a very exciting field of introductory astronomy courses. The most successful exoplanet detection method is the transit photometry. The aim of our study is to represent a cheap experimental setup for classroom demonstrations of the transit method and to analyse smartphone recorded transit track data by the FITSH software designed for real astronomical image processing, data analysis and planet characterization.

1 Introduction

Discovery and characterization of exoplanets, planet formation, determination of habitable zones and finding of Earth-like worlds are the most popular topics of the basic astronomy courses [1,2]. There are a number of methods for exoplanet detection in use such as radial velocity measurements through spectroscopy, gravitational microlensing or direct imaging, but the most common procedure is the transit photometry. Since the Nobel prize awarded discovery of an exoplanet orbiting a solar-type star in 1995 more than 75% of the 4528 confirmed exoplanets were found employing this method.

When a planet is orbiting it's host star and transits between the observer and the star, it shades the fraction of the star. This results in a measurable decrease in the observed brightness of the star. Plotting the star's brightness as a function of time, we get the concept of a light curve. Transits within our solar system can be observed from the Earth when Venus or Mercury is moving between us and the Sun.

The transit method of detecting exoplanets makes use of a sensitive light detector, usually placed on spacecraft, to measure small changes in the brightness of stars to look for periodic dips. The amount of time between the beginnings or ends of two transits is the planet's orbital period around the star. The measured orbital period and the mass of the star are used in Kepler's third law of planetary motion to calculate the planet's orbital distance. The size of the planet is determined by comparing the depth of the transit to the measured brightness and the size of the star. Transiting planets provide an opportunity to estimate mass and composition of these objects.

2 Experimental setup

Our experimental setup is inspired by the Dierking model [3]. As a model star we use a diffusive bathroom light cover with LED bulb (15 W, 1350 lm, 240-270° beam angle) which is placed in the middle of the carton box's ground base. The box is firmed using a wooden frame and dyed all around by blackboard paint. Various size rubber balls swinging on the string model orbiting planets. Model planets are rotating around the model star on a circular orbit employing an AC (24 V) synchronous motor removed from a microwave oven and a lever installed on the top of the box. We model the transit as an eclipse of an approximately spherical model star by an opaque sphere, as it is shown in Fig. 1. Unfortunately the modelled stellar disk is not of uniform brightness. As a light detector we use the PhyPhox [4] application running on a smart phone.

3 Data analysis

Having measured the light flux of the light bulb for a time interval that covers several transits, we plot the measured flux as a function of time. This allows selection of a singular transit event that we shall analyse. The size of the star and the planet determines the decrease in flux during the transit. Total transit duration highly depends on the so-called impact parameter (defined as the projected distance between the centre of the stellar disc and the centre of the planetary disc at conjunction). Measurement data was analysed using the FITSH astronomical software [5] with the idea to compare light curves obtained by different size model planets, as well as to calculate model planet's size compared to model star's size and total transit duration. Measured and calculated light curves obtained for the maximal transit duration, when the centre of the model planet crosses the centre of the model star (impact parameter is 0) are presented in Fig. 1. Difference between measured and calculated planet sizes and transit duration times is up to 5%.

Our further plan is to record and analyse light curves obtained by different impact parameters and orbit inclinations.

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Parallel 4 - Wroclaw / 98

Innovation in Kindergarten and Primary School Teacher Education in Physical Sciences

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Description

Symposium
Innovation in Kindergarten and Primary School Teacher Education in Physical Sciences.

Responsibles:
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Introduction
Innovation in Primary Teacher Education in Physics is crucial at a time of rapid development of science and technology in society and in response to the growing need for a modern scientific preparation of new generations to help them to cope with future challenges. The four contributions in this symposium come from four very different settings, giving fertile ideas that have matured in different contexts. They are united by their grounding in scientific education and primary teacher education research and develop our theme from two relevant points of view, i.e., integration and technology. Two contributions present integrated approaches to teacher education: the first integrates metacultural, experiential, planning and situated activities, while the second integrates nature, human and social disciplines. The remaining two contributions deal with the need to include engineering design and ITC technologies in school and in teacher preparation.
This symposium is sponsored by the GIREP Thematic Group "Physics Preparation of Teachers in Grades K-6" in view of its interest in knowing and discussing promising strategies to professionally prepare a new generation of kindergarten and primary school teachers.

Description of presenters:
Leslie ATKINS ELLIOTT, Boise State University, 1910 W University Dr, Boise ID 83725 (USA).
José CANTO', Experimental and Social Sciences Teaching Department, University of Valencia (Spain).
Marisa MICHELINI, Research Unit in Didactics of Physics, University of Udine (Italy).
Angelika PAHL, Bern University of Teacher Education (Switzerland).

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Integrating Engineering into Physics for Future Teachers
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Abstract. In the United States, the Next Generation Science Standards calls for engineering — and particularly engineering design — to be part of students' science education throughout primary school, with engagement in engineering practices integrated into students' learning of disciplinary core ideas. We describe how opportunities for engineering emerge in the context of a course on scientific inquiry for future teachers, efforts to expand on those opportunities to better align with engineering design, and how these opportunities differ in important ways from more typical engineering design activities. In addition, we argue that engineering activities can support and sustain rich, meaningful inquiry.

1 Background
The Next Generation Science Standards (NGSS) [1] calls for engineering — and particularly engineering design — to be part of students' science education throughout K-12, with engagement in engineering practices integrated into students' learning of disciplinary core ideas. However, few prospective teachers have an engineering background, nor are they likely to receive even a cursory training in engineering while in their undergraduate degree program.
And while designed artifacts (labs, devices) are central to scientific activity — a critical component of how scientific ideas are constructed — curricular examples of engineering for science are rare. Instead, existing curricula that integrate science and engineering primarily treat engineering as an application of scientific theory or a way of engaging students and inspiring scientific questions (e.g., [2]). For programs that hope to prepare science teachers to integrate engineering design into the development of scientific content, in ways consistent with NGSS, there are few models to draw from.

2 About the course
The course described here [3] is taking steps to address this. Initially the course was developed prior to NGSS, when the "inquiry standards" stood alone; therefore we focused on students' constructing and vetting scientific explanations without explicit attention to the correctness of those models or a commitment to the particular content being addressed. While instructors selected a phenomenon to launch our inquiry, this flexibility with content allows the course to be more responsive to questions that emerged. Topics varied, and included light, color, sound, astronomy, energy and time. Materials in the classroom varied as well, and are generally inexpensive, "everyday" materials (flashlights, plastic clocks), or "raw ingredients" (lenses, mirrors, inks, tape, string). These were available in the room or in an adjacent stockroom. When class is not in session, experiments were stored, not disassembled.
With the introduction of NGSS and engineering into primary and secondary education, we noticed the role played by designed artifacts in our course. Students frequently modify materials available, bring in new materials from home, deconstruct and reconstructing physical artifacts to support their inquiry. We identify these as rich moments to engage in purposeful engineering design. Below we briefly describe two exemplar moments. Our presentation will focus on these moments, efforts to capitalize on these for engineering design, and how they support and sustain engineering and scientific inquiry.
2.1 Opportunities for engineering
The two brief vignettes below describe how emergent questions sponsored opportunities for engineering design, which then informed our continued inquiry.
1. Absorption of light. As students in one course modeled shadows, a question emerged regarding the absorption of light: after how many reflections was our light too dim to be seen? One student constructed a kinked construction paper tube with a flashlight at one end. By placing the kinks so that she could no longer see the flashlight bulb, she was able to determine that, after 4 reflections, light from the bulb was essentially all absorbed (for black paper; 6 for white).
2. Measuring speed. In a semester focused on energy, students were using a Gaussian Gun to model energy transfers and transformations [4]. A debate arose as to whether the magnet itself provided energy to the ball; to resolve this students needed to measure that speed – for a ball accelerating rapidly over a very short distance. Among the more creatively engineered methods was the 3-d printing of a surface on which the balls would roll so they could record the sound and, from this, determine speed.

3 Conclusion
This presentation describes how opportunities to engage in meaningful engineering emerge in sci-

entific inquiry, and how we have capitalized on those moments to support engineering and sustain the inquiry as well.

Acknowledgements
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The virtual voice assistants in early science learning: an opportunity in Early Childhood Education
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Abstract. Technology is present in our lives and is also increasingly present in the classroom, as an educational tool. This fact must also have its transposition in the initial teacher training. This contribution presents a work in which virtual voice assistants are introduced as a tool in the teaching of science in early childhood education. We want to show the ideas from a group of 40 future teachers in their last year of the Degree, about the usefulness and the didactical possibilities of using virtual voice assistants as a tool in the teaching of science in early childhood education.

1 Introduction
In recent years, the common use of Information and Communications Technology (ICT), artificial intelligence and robots has spread across all educational stages including Early Childhood Education [1]. Consequently, children are exposed to digital devices from an early age. In addition, it has been proven that students work well in these digital contexts and even enjoy their use and the fact that they can speak directly to the machines [2] [3]. In this way it is not strange that in the educational field, we find that robots have been used as classroom assistants [4], or that they are even used as a tool to meet special needs in the classroom such as functional diversity or autism [5]. In this work we intend to reflect upon and investigate the usefulness of a particular multimedia resource that, for the time being, has not expanded into classrooms like those mentioned above: virtual voice assistants (VVAs).
Some works [6] [7] showed that VVA can have a greater impact on a child's cognitive development than when interacting with other devices such as computers or smartphones. In addition, they can also serve to modify many social dynamics both in the school environment and in the family environment. The key to the use of VVAs in Early Childhood Education for science is that the user interface is oral and is therefore accessible to children at this educational stage. To this, we must add that there have been significant improvements in current VVAs regarding the so-called error rate when specific questions are asked that allow a more fluid interaction with them. In this perspective, VVAs can be an effective tool to develop the potential of younger children while becoming a facilitator element for the teacher and allowing for autonomous learning. Other advantages of its use are its ease of installation (it only requires a power outlet and internet connection), its low economic cost, as well as the diversity of models available on the market (Amazon's Alexa, Apple's Siri, Google voice search…).

2 Methodology
Through focus group work, 40 students in the last year of the Infant Education Teacher degree at the University of Valencia (Spain) have reflected on the possibilities of using virtual voice assistants as a tool for teaching science in early childhood education. They have to address some questions, such as: What are the potentials of using VVAs in the classroom of childhood education as a teaching resource for science education? What needs come to cover these devices? How does the use of VVAs affect the role of the educator?

3 Conclusions
Students, analyze the different teaching uses that VVAs could have in the classroom of childhood education for science. Some of the conclusions they reached were the following:

• Stimulate oral communication since, with VVAs, can work communicative competence through the channel most suitable for one's age. This is essential so that children can express their ideas about natural phenomena.
• Be used as a source of information when researching in the classroom about a certain aspect of science that interests them to investigate.
• Use as a translator if a student who does not master the language of use is present in the classroom or you need a translation for some materials.
• Become an effective tool to accompany certain students who have special educational needs or even problems relating to their peers.
• Be search engines and narrators of oral resources for science education (stories,...).
The students concluded that the use of AVV can be very useful when considering the teaching of science in this educational stage. We believe that the use of AVVs can be a didactic tool that should be present in the science training of early childhood education teachers. For this reason, we are conducting a pilot study of its use in schools, where students in training train active teachers in its use.

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The Contribution of Physics Education Research in Educating Prospective Primary Teachers
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Abstract. Basic scientific education and teacher education are two interconnected problems studied in international educational research and physics education research, in particular. The Prospective Kindergarten and Primary Teacher education is a challenge for that scientific education competence that is able to promote children's critical thinking in an interpretative perspective in the exploration of phenomena and in building formal thought. The results of the last 20 years of research experimentation carried out at the University of Udine in the courses of Physics Education (DF) and Laboratory of Physics Education (LDF) in the third year of the five-year Master's program, that have produced the research-based consolidated formative model MEPS, are described in this article, including discussion of the different activities involved.

1. Introduction
   Extensive international studies have shown a lack of scientific education at all age levels [1], underlining the need for urgent actions connected to teaching professional education and development [2]. To focus on subject-related professional competence is an urgent challenge.
   The traditional models in teacher education, where pedagogical and subject-related education live in separate areas (in parallel or in sequence) leaving the integration to the prospective teacher is not working [3-4].

The future primary teachers have to modify the traditional scientific education, which is sometimes vague and not very incisive, or, on the contrary, is structured in disciplinary and transmissive ways, unable to prefigure the cognitive role of the disciplines, due to a lack of epistemic and methodological attention, which produces mnemonic learning, with poor operational skills, which extinguishes curiosity and reduces the motivation of learners. For Prospective Primary Teachers (PPT) and scientific education, the problem includes three main questions: 1) the need to improve scientific education starting from early childhood [6]; 2) the lack of solid subject preparation of PPT; and 3) the lack of teaching tradition, instruments and methods for scientific education in kindergarten and primary school [7]. Few are the valid teaching supports on which PPT can count, such as textbooks, brochures, software: the available materials for scientific education often present concepts not related to each other, and not infrequently are plagued with methodological errors (and not only). In addition, physics has no didactic tradition at the basic school level and the interdisciplinarity in the scientific field is confused with the generic treatment in popular terms: the formative, methodological aspects and the identification of conceptual elements are completely neglected in textbooks. Physics notions appear in a fragmented way, without founding them in sense-making, while the relationship with mathematics is often treated in other chapters of the same textbook with examples taken by everyday life action without taking the opportunity to explore and interpret common phenomena.
The PPT education is a research problem that goes beyond the integration of differentiated knowledge (Pedagogical and Subject matter knowledge), in favor of the appropriation of those competences that include how to organize teaching/learning path proposals, set up learning environments and activities, as well as knowing how to monitor and evaluate the learning process in the field, during classroom teaching. In Italy, the PPT education began in 2000 with a qualified project in a context unprepared for the task. This produced a research-based experimentation in the different universities [8]. The research-based characteristics and the results of the experimentation conducted in the Physics Education Course (DF) in the master's degree in Primary Science Education (SFP) of the University of Udine in the last 20 years are presented here.

2. Research
   For over twenty years, tools, methods and implementation models for the qualified professional education of future primary school teachers (PPT) are studied in the DF [5, 9, 10]. Research experimentation is carried out focusing on different aspects in PPT education [11-15]: 1) curricular contents and relative methods; 2) active role of PPT in their education; 3) instruments and methods; 4) role of planning; 5) integration of pedagogical, subject and transversal contribution in the master's degree; 6) curricular contributions to competence development and relative evaluation; 7) physics education research contributions; 8) role and impact of the school apprenticeship.
   The main research questions are:

3. How to produce familiarity in producing active scientific education in children starting from poor basic scientific knowledge?

4. How can planning educational paths produce competence in developing and evaluating learning scientific environments?

5. How can physics education research support the PPT education process?

3 Conclusion
Spontaneous teaching style of PPT is mutated by their experience in instruction, therefore is characterized by assertive presentation of notions and scarce involvement of learners: providing answers to questions not posed. Experiments are offered as observational news and interpretations of phenomena are not considered: the lack of relationship between science and math of textbooks is reproduced. The discussion of physics concepts in research-based educational paths produce familiarity with basic conceptual physics knowledge and offers examples of how to support learning experiences in pupils. This Metacultural educational activity is important in methodologic perspective change of PPT, but to gain awareness of the coherence in the educational paths discussed, they need Experiential experience by means of tutorials that they use in the same manner as their future learners: PPT have to experience the learning difficulties that pupils encounter in the learning process (RQ1). Planning educational paths is a useful exercise (RQ2), but can be a reductive reproduction of the research-based educational paths discussed as sequence of activities not well related with a poor attention to the learner role. We gain evidence of the need of the following phases: a) individual task in the perspective to work directly with children in school and attention to how to conduct each step; b) peer discussion in group of the path planned to reach an agreed Teaching Intervention

Module (TIM); c) discussion in plenary with the responsible of the DF course of TIM and its revision; d) preparation of education materials for the TIM in classroom with children; e) prepare and use monitoring instruments and methods during the implementation of TIM; e) analysis of the learning process during the intervention; f) reflection with a peer observing the implementation the work done and report on the learning in the field (RQ2).
Physics education research supports each step in each topic of the PPT education (RQ3) and in particular offers: a) research-based science education paths; b) studies on learning difficulties in the different topics; c) tutorials on different topics; d) experiments and educational materials; e) reflection on educational aspects as the interplay between math and physics concepts, interdisciplinarity, role of metaphors, of representations, of exercise, of experiments and exploration…; f) self-evaluation by means of PCK exercises; g) instruments and methods for learning process analysis.
The MEPS model [5] integrating M-metacultural, E-experiential, P-planning and S-situated activities is developed. An important part of the appropriation of competence in science education by PPTs is the integration of the discussions of research-based educational paths, with the designed paths by PPTs, and the analysis of the teaching intervention modules (TIM) prepared by PPT [10]. The outcome of such work makes the acquired skills operational. The Situated learning, produced from the field experiences in real classes and from the monitoring and analysis of children's learning paths and outcomes consolidate the professional competences that are acquired.

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Physics in Swiss Primary Teacher Education: A Multidisciplinary Approach

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Abstract.
First, this paper overviews the curriculum organization of science teaching in Swiss primary schools. It becomes clear that science education in primary school is part of the integrated subject "nature-human-society," which includes different natural and social sciences disciplines. Second, the multidisciplinary approach in teacher training for the subject "nature-human-society" is described, and student teachers' views are shown, which makes evident that the different content areas of this integrated subject are not equally popular among student teachers.

1 Curriculum Organization of Science Teaching in Swiss Primary Schools

Physics does not appear in the primary school curriculum, but physical contents and practices are still part of primary education. Physics is missing as subject because the natural sciences are usually taught and learned through an integrated subject, namely, science, and not in a disciplinary way [1]. In Swiss primary schools, however, science class does not occur as a single subject, but in still further disciplines integrating subject [2]. Science is merged with humanities and social sciences in one subject, called "nature-human-society." Since the introduction in 2016 of the new, common curriculum for German-speaking Swiss Primary Schools and the associated redesign of this subject, "nature-human-society" comprises four content areas: (i) nature and technology, (ii) geography, history, and society, (iii) economics, work and housekeeping, and (iv) ethics, religions, and community. With this multidisciplinary curriculum, the "nature-human-society" lessons should support and encourage primary school pupils to explore and understand their natural, cultural, social, economic, and technical environment to act responsibly toward their living environment [3]. The approach should assure a multidimensional view of learning objects and thus avoid children accessing their living environment in a fragmented way [4].

2 Multidisciplinarity in Teacher Training and its Acceptance by Student Teachers

The special composition of the subject "nature-human-society" requires special teacher training, which brings the different content areas in the teacher program together without adding them up one after the other in only an isolated way. The training allows students to develop an appropriate understanding of the multidisciplinary subject matter and acquire the subject-integrated pedagogical content knowledge to plan and implement appropriate learning units [5]. At the Bern University of Teacher Education in Switzerland, several lecturers from different disciplines (biology, physics, geography, history, economics, religion, science, and ethics) interact to conceptualize the modules for teacher training in "nature-human-society." However, due to the great variety of subject content, not all content can be elaborated in detail in the three years of teacher training. Student teachers may at least gain insight into the most basic concepts of all perspectives [6]. A survey conducted at the Bern University of Teacher Education showed that the popularity of the different content areas is not equally pronounced among student teachers. Also within the field of natural sciences were clear differences. Most student teachers prefer biological and dislike physical or technical content [7–9]. Therefore, in a multidisciplinary subject like "nature-human-society," there is always the risk that some content will be neglected in favor of others. Thus, during teacher training, it is even more important that student teachers' interest in and beliefs about different disciplines are worked on to develop a professionally positive attitude toward all perspectives of the subject "nature-human-society".

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Plenary 9 - Wroclaw / 99

Strategies for Active Learning and Assessment of the Learning Processes

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Abstract. Active Learning strategies are acknowledged to improve student understanding in many disciplinary fields. However, both the shift in learning objectives due to the use of these strategies and the recent need to implement active learning taking into account the requirements of mixed-mode teaching due to the COVID-19 pandemic pose the problem of developing and validating new assessment methods and techniques. In this Symposium, both examples of active learning activities focused on developing critical reasoning skills, like modelling and argumentation, and of assessment tools and methods will be presented and discussed.

1 Introduction to the Symposium
Active learning methods and strategies are credited with improving student conceptual understanding in many fields, including physics [e.g. 1-2]. This is possibly due to the strongly contextualized nature of active learning education, that emphasises on the interdependence of situation and cognition. When learning and context are put together, knowledge is seen by learners as a tool to be used dynamically to solve problems and develop critical reasoning, processes and transversal skills, rather than the final product of education.
In recent years, some innovative teaching and learning based on mixed mode real-virtual laboratories and model building, enhanced by the use of digital technologies, and aimed at actively involving students in their learning processes even remotely, has been conducted. This was further motivated by specific requests for distance learning coming from schools and universities due to the COVID-19 pandemic.
However, with the shift in teaching modes due to the pandemic and with learning objectives specifically related to active learning, focused on the development of skills and processes, the approach to assessment needs to change. New assessment techniques to review the entire learning process and determine the effectiveness of the active-learning approaches proposed to the students need to be developed and validated, [3].
The four talks part of this symposium will deal with the implementation of innovative active learning strategies, focused on hands-on and minds-on activities, on mixed-mode distance teaching, and on the activation of modelling and problem solving processes to actively engage and involve the

students. The development and use of formative and summative assessment tools will also be discussed.

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Constructing a deeper meaning through modelling

Abstract. My talk will describe my work in modelling and in particular, the connection between modelling and problem solving. Key to the theory of modelling is the realization that modelling is a natural activity. We form mental models to understand a problem and the construction of a mathematical models is, in essence, an extension of this kind of natural cognitive activity. That said, modelling is not an easy skill to acquire. Modelling is best regarded as a constructivist activity in which students actively participate in the construction of meaning. It is best undertaken in groups as a form of guided enquiry.

1 Introduction
In this talk I will describe my work in modelling [1] and in particular, the connection between modelling and problem solving. A key step in teaching students how to build models is the recognition that in order to solve a problem we have to build an internal, or mental, model of the problem. This kind of modelling is a natural activity. It is a key part of reasoning and the development of a mental model of the problem leads naturally to a potential solution and the construction of mathematical model. In short, building models is, in essence, no different from the kinds of cognitive activities we undertake every day and in this presentation I will elucidate this idea.
I will argue that models are causal or explanatory mechanisms built from concepts which in turn lead to the formation of new concepts. Concepts are here regarded as embodying relationships of one kind or another. These relationships can be causal, such as the relationship between a force and acceleration, temporal, such as the relationship between change in position with time, spatial, implying the use of vectors, for example, or probabilistic. It follows that in order to build a model, students need to understand a system. They need to be able to identify objects, such as masses and charges, and understand the nature of their interactions and relationships with other elements of the system. They need to be able to recognise the various forces present as well as their consequences.
Modelling is a constructivist activity. The act of building a model not only requires the modeller to recognise and use physics knowledge, as described above, the very act of modelling is a way of actively applying knowledge and thereby deepening understanding. However, there is a good chance that students either will not have encountered all the necessary physics or, if they have, that they will not understand it sufficiently to be able to use it effectively. Therefore, it is necessary to use problems that lie within the zone of proximal development, which, as defined by Vygotsky, is that space between what they can do unaided and what they can do with guidance and prompting. Providing guidance and prompting to ensure that students develop an effective model is thus essential to modelling as a method of active learning. It helps to ensure that students can actually build the models required to solve the problem and in so doing help them gain confidence in the process. However, as students develop at different rates and will need different amounts of guidance, it is best if models are built within groups so that students can exchange ideas and use their collective knowledge to understand the system and develop the model.
The process of building a model itself comprises three different, but not always distinct, stages. The first stage has been described above and involves developing a qualitative, mental model of the system. The second stage involves translating this understanding to a mathematical formulism and the third stage involves "running" the model and evaluating the outcome against the initial assumptions and expectations. Running the model does not mean running computer code, but developing the mathematics and solving the equations for the particular circumstances set out in the problem. Limiting cases or particular approximations might also be examined to test the validity of the model.
Modelling can thus be regarded as a process of making sense of the physical world and this connection with sensemaking is important. It is well documented that many students will approach simple problems as an exercise in finding the right equation to apply. They appear to lack an insight into the origin and meaning of the equations they seek, that they arise out of this process and reflect a

physical reality. Modelling is a process by which this connection between physics and mathematics is revealed and strengthened.
The process of translating from physics to mathematics and back again is taken for granted by professional physicists and poorly understood by educators who would like to teach students how to develop this skill. I will argue in this talk that modelling is a natural way to do this. I will argue that the development of iconic, analogical, qualitative mental models is a natural process and perhaps the dominant mode of reasoning in humans. I will further argue that many concepts imply mathematical relationships and that developing a mathematical description of a physical system follows naturally from a description of the system in terms of the basic concepts.
In this talk, the whole modelling sequence, from understanding a problem, to constructing a mathematical description and assessing the outcomes of the model, will be described along with guidance on how to implement this kind of approach within a class. It will be shown that translating between representations is key to this sequence and that an effective way of assessing modelling activities is to concentrate on the use of representations and in particular, the translation from one representation to another as students pass through the different stages of modelling.

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The physics of color, and its digital modeling, explored through a real remote laboratory (RRL) learning path.

Abstract. During the pandemic, a remote learning experience based on a mixed mode real-virtual laboratory, was conducted to respond to specific requests for distance learning coming from secondary schools. The peculiarity of this type of learning activity requires evaluation and assessment methods specifically taking into account the mixed real/virtual nature of lab activities and the purely virtual nature of the interaction among learners and between them and the teacher. In this contribution, some proposals will be presented and discussed, for the evaluation of learning outcomes and the assessment of both the learning process and in the aim of providing students with self evaluation tools.

The COVID-19 pandemic crisis, by suddenly requiring a shift of learning activities in remote mode, has hardly challenged the effectiveness of distance learning methodologies [1], especially in contexts where laboratorial activities play a central role. In fact, in emergencies, virtual laboratory (VL) is a substitute for the real laboratory (RL) [2, 3], as are the real experiments made with easily available materials, self-prepared by learners at home. However, the RL remains irreplaceable, especially in didactic setups relying on investigation-based laboratorial methods [4-5]. Despite its importance, the conventional RL is sometimes not available, as for example in the case of distance learning activities. In such cases, a possible substitute could be the "real remote laboratory" (RRL), where students run real experiments by remotely accessing true experimental apparatuses [6-7].
In this context, and in response to requests for training from local schools in Calabria (Italy), in the academic year 20/21 an RRL initiative of an innovative nature was designed and implemented, within an Italian national program (PCTO) aimed at fostering the transversal skills of high school students and at developing their specific knowledge and skills useful for adequately choosing the post-secondary training path. Since a distinctive feature of the PCTO program is to offer students the opportunity to participate in educational activities within a real working context, the learning path was framed within the research activities of the Laboratory of Applied Physics for Cultural Heritage at the University of Calabria, with particular reference to spectroscopic and colorimetric techniques applied to the conservative diagnostic of fine arts [8]. RRLs proposed in the literature (e.g. [6-7]) are very well-designed and useful, but require a considerable technical infrastructure, including some kind of physical control interface for the apparatus in the lab, and a software user interface to remotely access the apparatus. This means that such a kind of RRL cannot be set up extemporaneously to quickly respond to specific distance learning needs, as it happened during the Covid-19 pandemic. To address these limitations, we have devised and tested a different paradigm of RRL, structured as follows: (i) students are introduced to the problem and an inquiry-oriented experimental strategy is outlined; (ii) a human instructor executes the real experiments in the laboratory, while students are participating in video streaming from home; (iii) the experimentally acquired raw data are transmitted to students, who (iv) process them and, if necessary, ask the instructor for the possible execution of subsequent measurements, which will be performed in a subsequent session

in real time. Finally (v) information obtained from data processing are cooperatively discussed and conclusions are drawn. The learning activity is enriched by elements of web-mediated real time interaction, on the model of interactive lecture demonstrations [9], and all interactions among players (single students, university instructor, school tutors) are performed in video conference mode. The physics of the color, and its digital representation and processing, is the topic on which the learning path is contextualized, with particular reference to the modeling through color spaces, as the RGB model. The real experimental activities consist of various reflectance spectroscopy measurements on standard pictorial pigments, in order to investigate the relationship between perceived color and spectral shape of the reflected light. Moreover, the false-color processing method [10] has been introduced, to characterize pigments, discriminating between like-appearing colors corresponding to different spectral composition (methamerism).
In this contribution, after presenting the RRL learning path, a particular attention is devoted to the assessment-related issues. In fact, the peculiarity of this type of learning activity requires evaluation and assessment methods specifically considering the mixed real/virtual nature of lab activities and the purely virtual nature of the interaction among learners and between them and the teacher. Furthermore, given the orientation purpose covered by the learning activity, we discuss what kind of assessment (appropriate for distance learning with particular reference to RRL) is able to provide students with suitable vocational feedback, in order to help them orientate for post-secondary instruction. Attention will be paid to the evaluation of learning outcomes and to the assessment of the learning process, also in the aim of providing students with self-evaluation tools. An attempt will be made to compare the results obtained, with some works that have appeared in the literature in the meantime [1].

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How to help teachers to implement active learning strategies enhanced by formative assessment tools

Abstract. A large nunber of inquiry activities with teaching and learning materials has been developed within the national project IT Academy (2016-2022) implementing design-based research. They are designed respecting the principles of active learning, inquiry approach, digital technologies and formative assessment. The activities were trialed in the classroom in two subsequent cycles. Based on teachers´ feedback collected with the help of a questionnare the materials were modified

to get the final improved version. In the paper we present the research design as well as examples of developed activities at different levels of inquiry with suggested formative assessment tools.

1 Introduction
Active learning and inquiry-based approaches place student at the centre of the learning experience. In inquiry-based science education (IBSE) students are searching for an answer to a driving question working within a specific framework similar way as scientists do. There have been large effort invested in the implementation of IBSE as well as formative assessment tools. A number of European projects has been dealing with these issues, such as ESTABLISH, FIBONACCI, CHREACT or ASSIST-ME [1-5]. They motivated project partners to continue in these efforts at national levels. In Slovakia, large national project IT Academy has been running since 2016 [6]. Its main goals emerged from the imbalance between the current goals of the curriculum emphasizing IBSE and lack of instructional materials. As a result, one of the main goals is to support education by developing teaching and learning materials based on IBSE approaches enhanced by digital technologies and formative assessment tools.

2 Methodology
In order to achieve the main project goals, design-based research has been implemented. A number of experts in the field of physics education designed teaching and learning materials respecting the agreed criteria. Each lesson has been designed at a certain level of inquiry [7] starting with a driving question respecting the 5E learning cycle model [8] and is complemented with formative assessment tools. The materials were implemented in the classroom in two subsequent cycles. In each round they were reviewed by at least five teachers. Their feedback was collected leading to the updated version. The second trialing resulted in the final version of the materials that are presented online for a wide use of teachers and students.

3 Results
In physics, 80 lesson plans for upper and 78 lesson plans for lower secondary schools have been developed with materials for teachers and students (worksheets, exemplary filled-in worksheets for teachers, computer files, and other complementary materials). The important element of the lesson plan was the use of formative assessment tools. In the following we present examples of activities grouped on the basis of the specific formative assessment tool.
a. Making predictions as a natural part of the inquiry activities
The Predict – observe – explain strategy is used almost in every activity to predict the outcomes of an experiment. Predictions are compared with the experimental results and students´ explanations are explored in order to uncover their ideas. In the activity on law of momentum conservation, students predict velocity, momentum and total momentum of carts.
b. Peer assessment in project-based learning
In this activity students in groups work on the assigned research problems. At the end they hand in the project report with detailed description of the project goals, experimental design, data collection, their analysis and interpretation and conclusions. After that each group is assigned to review two other groups´ projects for evaluation and they fill-in the evaluation report. All reports are also commented by teacher who summarize results for the whole class.
c. Self-assessment as a strategy to reflect on own student´s learning
Many activites are complemented with self-evaluation sheets that make students to think about their own learning. At the same time it provides feedback to teacher. In the activity on Faraday´s law of electromagnetic induction students investigate the voltage induced in a coil situated between the poles of a turning horseshoe magnet. They analyze the experimental results for different parameters (frequency and number of coil turns) and reflect on the concepts and skills understanding in the self-evaluation sheet.

4 Conclusion
The experience from the implementation shows that teachers still need training in the field of IBSE and formative assessment strategies to fully understand their purpose and how to adjust teaching based on their implementation. We have designed online teacher education webinars where these issues are presented and discussed in detail.

Acknowledgements

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Strategies for Assessment of Inquiry Learning in Science

Abstract. Active learning methods receiving more and more attention require a design of assessment methods tailored to their goals and evaluation of the entire learning process. In the SAILS project, 19 science learning units in the inquiry-based learning approach were designed together with the whole spectrum of assessment tools. Each unit was tested in 3-8 classes, and the teachers reported their experiences in case studies. Teachers proved to be able to conduct the IBL lessons and use the assessment tools designed for formative assessment, however, their preferences for evaluation differed.

1 Introduction
In the last few decades, active learning methods have been receiving more and more attention as the best approaches to developing XXI-century skills. Unlike traditional methods, which are the most effective in delivering content knowledge at low levels of Bloom's taxonomy, active learning methods support developing competencies in their holistic form, comprising content knowledge, skills, and attitudes. They transform the classroom into a student-centered environment, in which students engaged collaboratively [1], discover the world by inquiry [2], and thus create their own learning paths. However, when active learning methods replace the traditional teaching approach, standard evaluation focusing only on content knowledge becomes inadequate. The mindset for assessment needs to change from standardized tests to the assessment tools evaluating the entire learning process, also during this process. So next to the summative assessment, a lot of teacher attention should be devoted to formative assessment. Such an approach has tremendous power in learning - as found by Black and William in their meta-analysis [3], intentional use of evaluation in the classroom (formative assessment) to promote learning unequivocally improved student achievements.

2 Inquiry-based learning and assessment
Inquiry-based learning (IBL) has been one of the most advocated active learning methods in science education over the last two decades is [4]. It leads to knowledge and understanding of the world by asking inquiry questions, formulating hypotheses, and testing them by collecting data during scientific experiments and using them as evidence to explain phenomena or events. In general, learning by inquiry follows a research cycle the researchers employ when they study a scientific problem. The concept of this pedagogy is not new; however, its educational potential has been increasing in technology-based societies [2]. It has been associated with increased students' motivation and interest in science, supporting the development of inquiry competencies and conceptual understanding [5].
As in any other learning environments and teaching/learning strategies, assessment in the IBL involves a collection of data, its analysis, formulation of conclusions and a feedback given to the students. Formative assessment (also called 'assessment for learning' [6]) serves the improvement of the learning process and is linked to the instant feedback given to students during this process. It can become relatively informal through on-the-fly interactions (informal formative assessment conversations [7]) or can be implemented more formally – with the help of evaluation tools and assessment plans prepared in advance (e.g., rubrics [8]). However, if used in the IBL approach, it should also reflect the goals and nature of this pedagogy [9-10].

3 Research and results
During the SAILS EU project [11], 19 science learning units in the IBL pedagogy were designed together with many ready-to-use assessment tools embedded into the material. More than 2500 teachers in 12 countries participated in SAILS teacher education programs with the IBL practical training based on the developed material. Each unit was implemented by 3-8 teachers and reported

as case studies. The assessment focused on a particular set of inquiry skills and competencies in every learning unit was proposed and associated with recommended evaluation tools. Brainstorming and classroom dialogue were assessed using checkboxes (Electricity unit) and less formally (on-the-fly) in most other units. In half of the units, teachers implemented self- and peer-assessment tools for the evaluation of collaborative work. Worksheets and other student-devised material were evaluated with rubrics in almost all cases. In one-third of case studies, teachers collected their assessment data in observations.
Most of the teachers followed the units and assessment strategies proposed in the ready-to-use materials, and a few of them willingly adapted units or assessment tools to their purposes. In general, the frequency of implementation of the assessment methods spoke for teachers' preferences. A closer look (e.g., Electricity unit) into case studies revealed that some of them felt uncomfortable with the evaluation tools the others reported as favorable.
So, the conclusion is that, when designing teaching materials user-friendly and beneficial for as many classes as possible, a broad spectrum of assessment opportunities should be included, both for formative and summative evaluation of the IBL approach.

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Parallel 1 - Wroclaw / 100

An educational experimentation on surface phenomena with elementary school pupils

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Abstract. Educational approaches to surface phenomena at elementary school are almost non-existent. Very little is known about the level of understanding of some specific properties of liquids connected

with surface tension at this schooling level. Here, we report the results of a comparison between two educational paths about surface phenomena. We show the results of a quantitative analysis of answers given to a questionnaire and also discuss the outcomes of a qualitative analysis.

1 Introduction
Educational approaches to surface phenomena at elementary school are almost non-existent. Very little is known about the level of understanding of some specific properties of liquids connected with surface tension at this schooling level [1,2].
Here, we report a comparison between two educational paths on surface phenomena at elementary school.
Two open-ended questionnaires consisting of questions that refer to everyday life phenomena and two educational paths, both based on laboratory activities, were designed. We administered the questionnaires to a student sample made of 42 third-year elementary school students randomly divided into two groups (control and experimental groups). The experimental group attended an IBSE-based path in which pupils were encouraged to be active part in carrying out the proposed experiments. The control group attended a more traditional path in which the teacher carried out the experiments and presented the results to the pupils.
We studied and compared the two educational paths through quantitative analysis of answers given to a questionnaire. We go in dept to the comparison by the outcomes of a qualitative analysis based on interviews, and other material produced by the pupils during the activities.

2 Results and conclusions
In the first analysis, we categorized the responses by founding the common conceptions. Subsequently, distinguishing them through the two categories, common knowledge and scientific knowledge.
The results obtained with the pre-instruction questionnaire showed a poor understanding of the phenomena related to surface tension in an equivalent way between the two groups. Moreover, a high percentage of unanswered answers was found.
At the end of the activities, the percentage of not given answers was very low. Moreover, an improvement in the quality of explanations and interpretations of the proposed phenomena was highlighted. No significant difference between the two groups was found.
However, the ongoing analysis highlighted a greater interest and a greater propensity for participation by pupils belonging to the experimental group. It was very satisfying to see how the pupils belonging to the experimental group built their knowledge autonomously, seeing them try the same experiment several times because they did not obtain the expected result or because they wanted to observe it again to grasp other facets. They provided a higher number of comments, questions and considerations throughout the experimental activities and during the lectures, reasonably demonstrating the greater aptitude of an inquiry-based approach to interest and involve pupils.

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Parallel 10 - Wroclaw / 102

Video Tutorials on Selected Topics in the Introductory-Level Dynamics

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Abstract. The lack of effective problem-solving skills is one of the stumbling blocks to students' success in the introductory physics courses [1]. The video tutorials described in this paper were envisioned as a supplementary on-demand resource that students could access 24/7 and study at their own pace. The authors focused on selected topics of Dynamics: such as Normal Force, Static and Dynamic Friction. These topics are known to be especially challenging for introductory level students. The resources developed for this project were used in the authors' own courses as well as other physics instructors at their university.

1 Project Motivation

Many students in introductory-level physics courses often cannot apply theoretical knowledge to problem-solving [1]. They often lack both conceptual understanding and math knowledge needed to plan and construct correct solutions. Learning effective problem-solving skills is even more difficult in large-enrollment classes [2], which are typical in STEM-based and premedical programs across North America. Quality open resources for physics based on the advances of Physics Education Research (PER) are still relatively scarce, while the need for such resources is great. A study commissioned by HEQCO to investigate the impact of active–learning strategies on students learning (conducted by the team lead by one of the authors of this paper in 2012-2013) revealed that students have particular interest in materials aimed at the development of problem-solving skills [3]. According to the survey, the students favor the format of short videos that demonstrate effective problem-solving strategies, and which model the expert problem-solving process. The students need the materials that can be accessed on demand, 24/7, at students' convenience. These materials can be used as pre-lecture assignments for a flipped classroom as well as for post-lecture reinforcement in a traditional lecture setting.

2 The Content Creation and Sharing

The tutorials were prepared in the form of dynamic Power Point slides. Since the tutorials targeted the topics in Dynamics, one of the essential goals was to provide the students with a tool to build Free Body Diagrams (FDBs) which are fundamental to successful problem-solving. Therefore, the basic animations illustrating FBDs development were added to the Power Point presentations. In addition, the animated screen display is supplemented with a brief text explanation. The presentations were narrated by the former student who took the course before. The presentations were then screen-captured by Camtasia, with an added voice over. For the current set of tutorials, the authors chose the topics of Normal Force, and the Static and Kinetic friction which present certain difficulties for many novice students. For example, the common misconception is that the normal force is always equal to the weight of the object. The tutorial created leads the students through the series of examples of how the normal force can be altered by applying an additional force having the component that is perpendicular to a contact surface, or by placing the object on an inclined surface. Another example is the typical misconception about static friction is that the force's magnitude is always equal to the product of the normal force and the coefficient of static friction.

The completed materials were shared with the instructors teaching introductory level physics courses at the authors' university. They are used already to teach 600+ students in introductory physics for science programs, with an additional potential reach of about 1,400+ students if used in engineering programs as well.

3 The Results and Conclusions

It is expected that the improved problem-solving skills achieved in the introductory courses has a lasting impact positive impact for the remainder of the students' University education. To receive objective feedback for the potential improvement of the materials, in the course offered for Science Programs students, the evaluations included targeted questions that assessed the learning outcomes for the topics addressed by the video tutorials. The results were compared with the baseline provided by the somewhat similar questions that were used in past years. Since the comparison year did not have the baseline questions for some of the subtopics, it was not possible to conclusively quantify the improvement due to the video tutorials.

The feedback from an informal voluntary students' survey indicated that overall, the students found the tutorials useful. In particular, the students believed that the tutorials focused on the essentials; learning from following the animated tutorials was more time-effective than from reading the static textbook sections; the mini-lessons are easy to follow; the animations in the tutorials are helpful for the visualizing the concepts. The students appreciate the ability to learn at their own pace: they can pause and re-watch the material as many times as needed. Several students indicated that they would like to see new videos targeting other challenging concepts.

This project is a work in progress. More video tutorials will be added. For the existing materials, more rigorous evaluation of their impact on students learning is being planned.

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Parallel 2 - Wroclaw/Guayaquil / 103

Expanding STEP UP - Encouraging Girls in Physics Globally

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Expanding STEP UP - Encouraging Girls in Physics Globally
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Abstract. The number of women in physics trails the number of men, despite efforts to change this representation. The STEP UP project aims to mobilize teachers to encourage girls to study physics, by changing classroom dynamics and having deliberate conversations about representation in physics. This workshop will explain the STEP UP lessons and highlights efforts to expand the program internationally. Educators will gain insight in how to have these challenging conversations, and how to get involved.
1 Gender Representation in Physics
Previously collected data shows that the percentage of women completing bachelor's degrees in physics has historically trailed behind other STEM fields in the United States [1], and in other parts of the world [2]. Several gender-dependent factors have been identified as alienating girls from physics: socialization patterns; self-efficacy towards physics; classroom culture; curriculum and assessment strategies; and teachers' beliefs and awareness regarding girls' engagement [3].
2 STEP UP
The STEP UP (Supporting Teachers to Encourage the Pursuit of Undergraduate Physics) project represents a powerful movement for high school physics teachers who are motivated to support and inspire girls in future studies in physics [4]. The project has developed guidelines for teachers along with two lessons that directly deal with the issue of representation in physics.

Figure 1. The precentage of bachelor's degrees earned by women in Science, Technology, engineering and mathematics (STEM) fields (left) [1] and specifically undergraduate physics degrees across different countries (right) [2].

The Everyday Actions Guide is designed to develop equitable classroom culture, providing teachers with a self-reflection questionnaire to help them consider how they interact with students, and if their work promotes inclusivity in their classroom. The Careers in Physics Lesson has students explore profiles of individuals with a degree in physics and identify goals that can be accomplished with skills learned in a physics degree. Students are encouraged to assess their personal values and see how they match with the values of people already working in various careers, learning that physicists are in jobs that help others and the world around them. The Women in Physics Lesson examines the conditions for women in physics, drawing on current statistics and research (Fig. 1). The goal of the lesson is to help students reflect and think critically about the issues of underrepresentation in order to counteract bias. The lesson has students examine the conditions for women in physics, discuss gender issues with respect to famous physicists, and share personal experiences.

3 International Efforts
Over the past three years, the STEP UP Project has worked to get teachers using the lessons in their classrooms, with international teachers increasing in number. In the 2019-2020 school year, forty-five teachers from across the United States were selected as STEP UP Ambassadors, to receive training on the lessons and then train other teachers, empowering them to inspire young women to pursue physics. In the 2020-2021 school year, the number of teacher ambassadors increased to eighty teachers, including two international teachers - one from Canada and one from Brazil. These two international ambassadors were tasked with sharing the lessons to teachers in their home countries as well as generating translations and adaptations for their local contexts. For the 2021-2022 school year, the model of teacher recruitment changed, with a group of twenty-one ambassadors staying on as teacher leaders and one hundred and eighty-six teachers (referred to as teacher advocates) who will receive direct training on the STEP UP lessons. The group of advocates includes ten international teachers from eight countries (Fig. 2). Efforts are underway to develop an international set of career profiles, and translate the lessons into more languages.

Figure 2. The location of STEP UP's International Ambassador Lead and Advocates.
4 Conclusion
The STEP UP Lessons represent a way for teachers to encourage their female students to study physics, and help change the representation in the field. Research has shown that the STEP UP lessons have benefits for all students' belief in a future physics career, and had increase benefits for young women. This workshop will give educators an overview of the STEP UP lessons and guiding principles. In addition, opportunities for educators to get involved with the program will focus on international efforts.

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Parallel 9 - Hanoi / 104

Development of The Bicycle Power Generator for Energy and Environmental Education

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We have developed a highly versatile bicycle power generator for energy and environmental education that can be mounted on a variety of commercially available bicycles and can be used to operate familiar household appliances.

Parallel 6 - Hanoi / 105

Development of Concept Inventories fitting Japanese High School Physics I

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We have been developing concept inventories fitting to the standard curricula for Japanese high school physics. A "trial" version of the test has already been completed. As a preliminary study, we have administered the test to 2559 Japanese high school students under pre-instructional conditions and analyzed obtained answers statistically. The results suggest that some test items need to be improved. In this talk, we will show an overview of a project on this development and test-data analyses.

Parallel 5 - Wroclaw/Guayaquil / 106

Differences and similarities in approaches to physics LAB-courses

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Many universities attempt through their lab courses to teach students how to successfully engage in physics inquiry. It is known that doing so effectively requires students to participate in genuine inquiry: Learning to do science by doing science. Still, many different approaches can be envisioned. Should students always pose their own research questions, or should we gradually allow them more freedom? What minimum knowledge is required before they can reason with scientific evidence effectively and how do they acquire this knowledge in a meaningful way? How much time should be devoted to teaching students how to communicate their results in different formats, and how can we improve the quality of their writing? And, if we succeed in designing a course with which this broad goal can be attained, what is the workload for both students and teachers? What tools do we have to evaluate whether students master the knowledge, skills and competences that allows them to participate in more complex and independent physics inquiries in later years?

In this symposium, we compare the approaches to physics LAB-courses of four universities: University of Colorado Boulder (UCB), Amsterdam University College (AUC), Leiden University (LU) & Delft University of Technology (DUT). Each presenter will provide an outline of the approach and

the rationale for it. One of the experiments or activities that is representative for the specific course will be highlighted.

Once the different labcourses have been outlined, we will discuss their similarities and differences more deeply, with specific attention to difficulties encountered and overcome. The questions and topics addressed above will be the point of departure for an engaging discussion.

Parallel 6 - Hanoi / 107

A Report on the Results of Electric Circuit Concept Survey Tests in the Teacher Training Course, from 2001 to 2020.

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We carried out a survey test of the concept of electric circuit to investigate the understanding of these concepts at primary school level by students on teacher training courses for 20 years. The results shows that students were not able to understand simple circuits, although improvements in textbooks and curricula used in primary schools. The lack of understanding of the circuit itself and of the inner workings of a bulb was evident. Further analysis revealed that there is an increasing number of people who do not care about the internal structure of the bulb.

Parallel 10 - Wroclaw / 108

The many roles of metaphors in learning and doing physics

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Abstract.

In recent years, the physics education community has explored the role of conceptual metaphors in the teaching and learning of physics. While researchers seem to agree on the crucial cognitive value of metaphors that can aid scientific inquiry, their instructional potential in physics education is not yet fully realised. In this paper, we first review the many roles of metaphors in learning and doing physics. Synthesising insights from the history and philosophy of science and physics education research, we then show how the explicit use of metaphors can improve instructional practices in physics education.

1 Introduction

Metaphors play a crucial role in science by providing aids to reasoning and imagination (1). Metaphors can also provide the basis of scientific knowledge that is too abstract to be understood through our senses alone (2). Although the extent to which metaphors constitute an essential part of scientific knowledge is still a debated topic among scholars, there is no doubt that metaphors have excellent potential to improve instructional practices in physics (3). However, there remains a gap between research and practice. While physics education researchers have argued for the importance of conceptual metaphors (4,5), few instructional practices make explicit use of such metaphors (6). We address this gap and suggest ways of bridging it. First, we review the roles of metaphors in learning and doing physics. Second, we synthesise findings from the history and philosophy of science (HPS) and physics education research (PER) to suggest how physics teachers can take advantage of these different roles. Two research questions guide our inquiries: 1) Which role do metaphors play in learning and doing physics? 2) How can metaphors be put to good use in physics education?

2 The role of metaphors in learning and doing physics: insights from HPS

Metaphors play a crucial role in scientific knowledge construction: metaphors can serve as aids to reasoning, and specifically, as aids to imagination (1). By suggesting directions of inquiry, metaphors guide scientific thought. Many historical accounts describe how physicists drew on metaphors to develop their scientific imagination and develop and refine physical theories. Prominent examples include

1. Newton's efforts to understand the nature of light by comparing refracted light rays through a prism as "tennis balls" describing curved lines (7).
2. Faraday's metaphorization of his early intuitive conception of lines of force as vehicles moving, shaking and undulating when transmitting magnetic and electric forces (8).
3. Einstein's thought experiments gather many conceptual metaphors to grasp essential features of the general theory of relativity (3).

3 The role of metaphors in learning and doing physics: insights from PER

To understand the role of metaphors in learning and doing physics, physics education researchers have drawn on conceptual metaphor theory (3,5). According to these perspectives, our understanding of physics concepts is grounded in our bodies, and we extend embodied experiences to more abstract domains through conceptual metaphors. Here, the role of metaphors in learning physics is constitutive: metaphors are conceptual mechanisms that evoke lived experiences as an experiential basis for the construction of abstract concepts. There is another role of metaphors that extends the cognitive linguistic view of conceptual metaphors: enactive metaphors build on the idea that metaphorical meaning emerges from human actions and is closely embedded in the environment. While conceptual metaphors transfer embodied experiences to more sophisticated cognitive structures, enactive metaphors demonstrate the relevance of action-based metaphors for learning (6).

4 How can metaphors be put to good use in physics education?

We have gathered insights from HPS and PER to identify three roles of metaphors in learning physics:

1) imaginative role: metaphors as aids to imagination
2) embodied role: metaphors as conceptual mechanisms of knowledge transfer
3) enactive role: metaphors as figures of action.

We now turn to instructional implications and briefly sketch how addressing the embodied role of metaphors can improve instructional practices in physics education. In our talk, we will also elaborate on instructional opportunities for the other two roles of metaphors.

Conceptual metaphors: If our understanding of physics concepts is grounded in our bodies, teachers can ground instructional activities in embodied sources (6). Such grounding can mean choosing instructional metaphors with embodied sources (3) or letting students perform concrete kinaesthetic activities that link to scientific concepts. One exciting implication of combining the imaginative and embodied roles of metaphors is that metaphors could be considered as imaginary laboratories for conceptual change.

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Parallel 6 - Hanoi / 109

Explanatory approach for analyzing online problem-solving activities in science teachers' CoP with epistemic tools

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The aim of this study is to describe an explanatory approach for analyzing logical structures of science teachers' inference process with epistemic tools. The epistemic tools used in this study were the following concepts of epistemology: Inference to the Best Explanation (IBE), Explaining to the Best Inference (EBI), testimony, and theories of scientific explanations. The online problem-solving activities in science teachers' Community of Practice (CoP) were analyzed. The result shows their professional competence to do scientific investigation in CoP. The logical structure of science teachers' problem-solving activities also suggests some ideas to design students' exploring activities in class.

Parallel 8 - Wroclaw/Guayaquil / 110

Investigating the relationships between students' reasoning in Socio-Scientific Issues and knowledge about scientific inquiry and modelling

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In this paper, we investigate the relationships between students' reasoning about socio-scientific issues and their knowledge about scientific inquiry and modeling. To this aim, we developed a teaching-learning sequence for high school students (10th grade) using the controversial scenario of the closing of a steel manufacture plant. The results show that students' knowledge of models and the scientific inquiry does not seem adequate to achieve a sufficient level of competence in socio-scientific reasoning. Implication for teaching practice about physics-based socio-scientific issues will be briefly discussed.

Parallel 7 - Wroclaw / 111

Helping teachers bring modern physics into the classroom: an example of collaboration between University and School

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Abstract. Creating a fertile space where University and School share knowledge and experiences is increasingly important, and teachers' professional development initiatives can be the right place to do it. For this reason, at the Department of Mathematics and Physics of Roma Tre University we realized a course on modern physics where, after a brief introduction to the main topics, participants were asked to design high school lessons complete with all the related teaching material, under the guidance of University tutors. Some of the produced materials have already been tested by the involved teachers or will be tested in the coming months.

1 Introduction

In recent years more and more efforts are made to introduce modern physics at pre-university levels, and thus give a more realistic and updated view of physics to high school students. In this context, Universities may play a key role in teachers' professional development on the most recent aspects of scientific research, and Physics Education Research can represent the driving force capable of nourishing not a mere passage of physics notions, but the cooperative development of teaching materials that can be immediately used in the classroom. The professional development courses usually offered by Universities to high school teachers - such as the many initiatives from the Italian/National PLS-Piano Lauree Scientifiche (plan for science degrees) [1,2] - can provide the environment in which teachers and researchers can meet, discuss and analyse the new concepts and the way of bringing them within the classrooms, thus building together that Pedagogical Content Knowledge so crucial to create effective teaching. Following this idea, at the Department of Mathematics and Physics of Roma Tre University we realized an online teachers' professional development course during which, after a brief introduction to the main topics treated, participants created themselves didactic materials concerning modern physics under the guidance and supervision of University tutors.

2 Results

The teachers' professional development course was held entirely online in the period October 2020 - January 2021 and involved about 50 high school teachers. We used Zoom for the online synchronous meetings during which all teachers and tutors could intervene like in a virtual classroom; moreover, a Moodle platform was used as a space in which to collect materials and share comments and ideas among participants. The course started with the presentation of a series of theoretical materials prepared by the Department that could be immediately used by teachers in their classrooms with their students. As participants already had basic knowledge of modern physics, these materials also served as a short theoretical review of the main concepts. In addition to these resources, we also shared with the teachers some more practical and laboratory proposals. For example, regarding Einstein's Relativity, we introduced a series of activities based on the use of the rubber sheet as a space-time simulator [3-5]. All the presented activities were discussed among participants, and their positive and negative aspects, together with and their feasibility at school, were evaluated. This initial phase thus also served to break the ice, start discussions, and create the group.
We then moved on to the most active work phase. Participants, divided into small groups of 3-4 people, began to autonomously work on a topic provided for by National Indications for high school, with the guidance of a University tutor. The aim was to design lessons complete with all the related teaching material: presentations, insights, bibliographies and laboratory sheets. Once a week a common virtual synchronous meeting updated everyone on the state of the work, and provided the opportunity to discuss limits, potential and possible improvements of the materials produced together with University staff. At the end of the course all the groups presented and shared the teaching materials they produced.

3 Conclusion

The teachers' professional development course we proposed was very well received by participants, as confirmed not only by evaluation questionnaires we administered, but also by the enthusiasm with which participants actively got involved in the work. At the end of the course a series of ready-to-use educational materials on modern physics were produced combining teachers' educational experience with University expertise. Some of the materials have already been tested by participants with their students, but further tests will be carried out in the coming months.

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Parallel 9 - Hanoi / 112

Unearthing student teachers' Physics misconceptions during Work-Integrated Learning

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Abstract. This study explored student teachers' Physics misconception during Work-Integrated Learning in high schools in South Africa. The sample in this work comprised eight final-year student teachers pursuing a Bachelor of Education degree and seven Postgraduate Certificate in Education students. An unstructured observation method was utilized to collect data during the lessons that were conducted by the participants. It was observed that a significant number of the participants had some misconceptions about Physics. Some of participants claimed that their misconceptions emanated from the prescribed textbooks and also from their previous studies. A number of suggestions were made to remedy this grave issue of Physics misconceptions amongst the student teachers.

1 Introduction
Physics as a school subject is generally viewed as difficult to comprehend and master due to a myriad of reasons [1], [2]. In South Africa, Physics is offered jointly with Chemistry as Physical Science for high school learners between grades 10 and 12. Generally, the pass rate and quality of the grade 12 final matriculation results in Physical Science is very poor [3], [4]. The study in [5] reveals that one of the main reasons for learner poor performance in Physical Science is that a significant number of the teachers may not have specialized in teaching both Physics and Chemistry, and in this particular study, most of the teachers were not competent enough to teach Physics at the required level.
Although much effort has been expended in studying the reasons behind matriculant learners' poor performance in Physical Science, there is presently no literature that explores the role that student teachers' misconceptions in Physics plays in the overall performance of the learners in South Africa.
2 The body
This study utilized an unstructured observation method to collect data from eight final-year Bachelor of Education degree and seven Postgraduate Certificate in Education Physical Science student teachers who were on Work-Integrated Learning (WIL). During WIL, I was assigned to assess the students on a variety of issues by using a standardized rubric for assessment. I then concurrently wrote seperate notes during the lesson observations that were primarily aimed at revealing Physics misconceptions that arose during the lessons.
The results showed that a significant number of the student teachers held deep misconceptions about key Physics concepts. Most of the ensuing misconceptions were found to be in Mechanics and Electricity and Magnetism. During the discussions after the lessons, some of the students openly stated that the misconceptions that they had arose from the information that they obtained from the prescribed textbooks, and others were adamant that their conceptions emanated from some of the modules that they had previously studied.

These results overtly pointed out that some of the high school learners' misconceptions are passed on to them by their teachers who would have some deep-seated flawed conceptions on certain Physics phenomena and concepts.
In a follow-up to this study, I intend to examine a number of the prescribed textbooks to find out if indeed some of the misconceptions that the student teachers held originated from the books as alleged by some of the participants

3 Conclusion
A significant number of student teachers held some serious misconceptions on a number of Physics topics that will certainly be passed on to their future learners. Serious intervention strategies need to be put in place to address this menacing challenge that certainly places the advancement of Physics education at risk.

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Parallel 1 - Wroclaw / 113

Cooperative learning approach in secondary school physics lessons

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The aim of this study was to identify the effects of the cooperative learning approach in higher secondary physics classes on the topic of thermodynamics. Students followed two different methods: one group followed frontal work (FW) and the other followed cooperative learning (CL). Data were collected using a knowledge test and a questionnaire. 49 secondary school students participated in the study and a pre-post design was used. The group that followed CL increased their knowledge more than the group that followed FW. Based on the results, it is recommended that teachers should be encouraged to use cooperative strategies in the classroom to teach selected physics concepts.

Parallel 10 - Wroclaw / 114

University students understanding of the moment of inertia in a rotating rigid body

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University students understanding of the moment of inertia in a rotating rigid body
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Abstract. It is well known that the comprehension of the moment of inertia is essential to understand any phenomenon of the rotation of a rigid body. The objective of our study is to inquire into the conceptions of university students when they explain the role of the moment of inertia in phenomena of rotation of a rigid body about a fixed axis. We have designed an open-ended questionnaire for students in a calculus-based introductory physics course. The questions were designed following an epistemological analysis in order to raise the key concepts needed to understand the moment of inertia of a rigid body properly. In this study, we intend to find different ways in which students interpret significant aspects of the moment of inertia, through the analysis and understanding of students' explanations. We will present a number of the questions and results.

Introduction

In many undergraduate physics courses, the program begins with Mechanics because most of the subjects are a review of physics in High School courses and it is considered that the students will not have significant difficulties in their learning. However, understanding the kinematics and dynamics of circular motion is difficult for students. The literature has shown that high school and university students present some difficulties in understanding particles' rotational movement. The research reveals that a significant amount of students think that a particle describing a uniform circular motion does not have acceleration, that no force is needed to produce circular motion and they consider centrifugal forces as "real" even for an inertial frame of reference [1]. Students show difficulties distinguishing between linear and angular acceleration and between linear and angular velocity. Moreover, they show difficulties distinguishing between centripetal force and acceleration [2,3]. We expect that the gap in the comprehension of the concepts grows up when the particle is substituted by a rigid body.

The objective of our study is to analyze how first year university students recognize and apply the concepts of moment of inertia for a rotating rigid body. The aim is to relate the ability of students to apply this concept with their understanding of it. We want to detect students' comprehension difficulties when learning the concepts of moment of inertia at undergraduate physics courses. The motivation behind this study is to know the level of understanding that students have after instruction in introductory physics course at University. This knowledge constitutes a relevant contribution when designing the didactic material to be implemented in lectures.

Experimental design and methodology

We conducted a study with 82 students from first course of engineering of the University of Basque Country (UPV/EHU). All students take two physics courses involving topics on mechanics electromagnetism during postcompulsory education (16–18 years old). The students were randomly distributed among the first year engineering groups. All students were finishing the first semester of introductory physics in the first year of engineering We gave students an open-ended questionnaire (8 questions) after they had studied the rigid body rotation, where rotation was considered to be around a fixed axis in space.

Regarding the validation of questionnaire, once the questionnaire had been prepared, three professors. They concluded that the objectives of each question were clear but suggested some changes to the wording of two questions, which were made by the authors. Moreover, we carried out a draft test with 25 first-year course students, which confirmed that students had no problem understanding how the questions were formulated. Finally, the questions were included in the first-year students' test in the form of a post-test for first third-year students who had already completed the semesters of Mechanic.

Findings

We analyzed data with a phenomenographic [4] qualitative method, considering the categories that emerge based on the students' approach to each question. The categorization process was validated by three researchers, and the classification of students' answers into categories was supported by Cohen's kappa ($\kappa = 0.92$).

We found that around 45% of students have a good declarative knowledge about of moment of inertia in a rotating rigid body around a fixed axis but we also found they have diferent difficulties. Around 40% of students do an incorrect analysis of the variables included in the deficintion of the moment of inertia for particles (I=Σ_i⊠m_i r_i^2) or they do the calculation based on a functional reduction regarding only m or r.
When we ask about the angular acceleration showing two cylinders (one solid and onw hollow) with the same mass and radius while the same torque is applied upon them, we see that students around 25% of students apply the Newton's second law for rotation but the don't really undertand the relation of the angular acceleration with the mass distribution. There is another 15% of students that claims that greater moment of inertia implies a greater angular acceleration.

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Parallel 8 - Wroclaw/Guayaquil / 116

DO STUDENTS' ATTITUDES TOWARDS PHYSICS DEPEND ON GENDER?

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The purpose of this study was to analyze whether high school and university students' attitudes towards physics show evidence of a gender bias. To this aim, we used a new framework, the Semiotic Cultural Psychological Theory (SCPT). A view-of-physics questionnaire was used as instrument to collect data with 1,603 high school and university Italian students. We identified four attitudes towards physics: a) interesting and important for society; b) quite interesting, but not useful for society; c) difficult and irrelevant for society; d) niche that protect from society. The identified attitudes do show a significant gender bias but with a weak effect.

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The role of experimental activities according to preservice Physics teachers during a Supervised Internship

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Abstract. This research sought to investigate, using Pecheutian's Discourse Analysis, which representations are attributed by future Physics teachers to the role of experimental activities developed during the activities of a Supervised Internship. The results show that, in their teaching practice, preservice teachers reproduce the practice of their professors. Furthermore, during the planning of their classes, academic productions in the area of education hardly are considered.

1 Introduction

The gap between theory and practice, and also between university and schools of basic education, is already discussed by several researchers in the field of Science Education, among them, Pimenta and Lima [1], stating that this situation happens soon in initial teacher training.
According to the aforementioned authors, the Supervised Internships developed in undergraduate programs (called "licensure" in Brazil) can be considered as a privileged moment of teaching training. It allows to cross all the subjects present in the curricular structure, in addition to constituting a space for synthesis at the end of the degree. It is also responsible for bringing the future teacher closer to the professional reality, characterizing itself as an important moment of teacher education, which provides opportunities for critical reflection in the social practice of educating [1].
Pimenta [2] also criticizes the fragmentation of teaching knowledge, arguing that they are worked separately and in a disjointed way. In this sense, as a way to overcome this problem, this research aims to investigate how preservice physics teachers interact with academic production, related to experimental activities in physics teaching, and also how they benefit from it for the planning and development of practical classes. For this purpose, we sought answer to the following question: What representations are attributed by preservice physics teachers to the role of experimental activities?

2 Experimentation in Science Teaching

Experimental activities are identified, both by teachers and students, as an important didactic resource to be used in the classroom, with the aim of reducing the difficulties of teaching and learning science [3].
Hodson [4] and Wesendonk [5] associate in three dimensions the characteristics of scientific knowledge, the aspects that experimental activities have in relation to the objectives and approaches that are intended to be achieved with the teaching activity: a) Conceptual Dimension: which seeks to help students to learn (elements of) science (specific scientific area); b) Epistemological Dimension: which seeks to help students learn (elements) about how science (specific scientific area) is constructed and developed; c) Methodological Dimension: which seeks to help students learn (elements) about how to do science (specific scientific area) [5].
Wesendonk [5] also considers experimentation in three modalities to be developed by teachers in science education: experiments with physical apparatus, thought experiments and computer simulation. For experiments with physical apparatus, the author characterizes four types of experimental activities: a) experimental demonstrations; b) predict-accomplish-explain; c) experimental verification; d) experimental resolution of a student's reality problem.

3 Theoretical and methodological referential

The theoretical and methodological framework adopted in this research is the Pecheutian Discourse Analysis (DA). According to Orlandi [6], discourse is given as a way of materializing the manifestations, both of the relations of forces and of meanings, which reflect conflicts of an ideological nature. In this sense, there is no discourse without a subject, nor a subject without ideology. The subject is descentered and positions himself within ideological formations, does not produce his own meanings and has no control over what he says or thinks [6].
Seeking to understand the effects of the meanings produced, it is important for DA to know and consider the context and conditions of production of speeches. In this sense, this study is organized during the activities of the Supervised Internship, in which future teachers planned and taught a short course. The corpus of the research was constituted from the speeches produced by the undergraduates in three moments of the Supervised Internship: before, right after the regency and at the end of the Internship.

4 Conclusion

The results show that, when planning the practical activities of the Internship, future teachers have the proposal to carry out experimental activities under an investigative perspective. However, in their teaching practice, they end up reproducing the practice of their professors. In addition, even with their speeches indicating criticism of the traditional teaching model, when preparing their classes, academic productions in the area of education hardly are considered.

Acknowledgements

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Parallel 10 - Wroclaw / 118

Understanding the relation between classical and quantum mechanics: prospects for undergraduate teaching

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Classical and quantum mechanics are two very different theories, each one describing the world within its own range of validity. According to Planck's version of the correspondence principle, classical mechanics is recovered when the limit in which Planck's constant h goes to zero is taken, while within Bohr's version the limit of large quantum numbers is taken. However, despite what suggested by many textbooks, the relation between the two theories is much more complex to state and understand. Here we deal with this issue by analysing some key examples. Implications for quantum mechanics teaching at undergraduate level are carefully discussed.

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Physics Undergraduates' Conceptions about the Nature of Science

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This research aimed to identify the epistemological profile of academics enrolled in the degree course in Physics, in 2021, at the central campus of UFMS, to guide pedagogical interventions that promote an adequate understanding of the nature of science. As a theoretical and methodological framework we used the VNOS-C questionnaire (Views of the Nature of Science, Form C). The interpretation of the collected data allowed us to assess that the students' conceptions about the Nature of Science are close to those of positivism and dogmatic rationalism, suggesting the need to work with elements of critical epistemology.

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Relativity and 1919 Eclipse: A Historical Study

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Popular narratives and textbooks claim that Einstein's Theory of General Relativity was proved during the observation of the 1919 eclipse. However, this version, in addition to being historically mistaken, reproduces an inadequate and distorted view of the nature and construction of scientific knowledge. In this essay, which through a literature review in historical sources, presents a synthesis of this historical episode, the observation of the 1919 Eclipse, denouncing historical inaccuracies and conceptual deformations, providing some suggestions on how to approach the history of science to the physics education.

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Dulong-Petit's law and Boltzmann's theoretical proof from the Kinetic Theory of Gases – Historical implications to the teaching physics in high school and its didactic transposition

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Abstract. The main aspect that we will discuss in this work is the presentation of the law of specific heats by Dulong and Petit, from an experimental and theoretical point of view, comparing with the publication of Ludwig Boltzmann's doctoral thesis in 1866. According to Cássio C. Laranjeiras [1], it is in his thesis that Boltzmann will do the analytical demonstration of this law for the first time. Determined experimentally by the two French physicists and published on April 12, 1819 [2] this law it very important to the after development of physics and will have fundamental implications to the quantum mechanics and can be considered the starting point for changes in the interpretation of Newton's classical mechanics.

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Development of Concept Inventories fitting Japanese High School Physics II

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This talk is the latter of serial presentations, and an overview of our project and method of test-data analyses will be shown in the previous one. The purpose of this study is to develop concept inventories fitting to the standard curricula for Japanese high school physics. In this talk, we will show some examples of a "trial" version of the test and discuss student's misconceptions based on student's responses to it. For example, by making an item related to sushi and improving the items of the existing concepts inventories, we made the concepts inventory in the context familiar to Japanese students.

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The Critical Pedagogy of Paulo Freire in the Constitution of the Professional Identity of a Physics Teacher Educator

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Abstract. On the centenary of Paulo Freire, this research investigates the contributions of the Critical Pedagogy in the constitution of the professional identity of a Physics teacher educator. Through a semi-structured interview interpreted from the postulates of the Pecheutian Discourse Analysis, it is found that the life history, the critical reflection in the praxis on the Teaching of Physics, Physics and the problems of initial formation, as well as the fight against scientific denialism and the hope for the ragged of the world are constitutive of the identity of the formator.

1 The interface between teacher education and research in physics teaching from the Freirean perspective

Paulo Freire's dialogic-problematizing educational conception continues to represent a theoretically revolutionary alternative to the current impasse of scientific obscurantism experienced in the world, particularly in Latin America. From Freire's perspective [1], education is a form of action based on critical reflection and social transformation. Such understanding is guided by the formative proposition that men and women are unfinished subjects who seek their conclusion through critical reflection. According to Freire [2], education is an exclusively human manifestation, as it occurs in the consciousness of men as unfinished beings. Thus, education is remade in praxis, that is, in the action and reflection of men, aware of their inconclusiveness, for the transformation of their reality. In the context of such discussions, this research aimed to investigate the following question: Which assumptions of Freirian's dialogic-problematizing educational conception are evidenced in the discursive materiality of a future Physics teacher educator attending graduate program in Science Education?

2 Discourse Analysis as a theoretical-methodological contribution

Just as Freire reflects on the unfinished man, the discourse analysis ponders the issue of the incompleteness of language, since, according to Orlandi [3], neither subjects nor meanings are complete, already made, definitively constituted. Therefore, the constitution of the research corpus occurred through the recording of an interview, in which the participating teacher reflected on her formative process, the impacts of Paulo Freire on her representation of the teaching profession and the way in which Freire's theories can be appropriated in the processes of construction of scientific knowledge evidenced in the current challenges of the initial formation of Physics teachers. For the discourse analysis, an analytical device was built based on Orlandi [3] and the assumptions of the Freirian dialogic-problematizing educational conception [1-2].

3 Results and discussions

The contributions of Paulo Freire's Critical Pedagogy are interwined in the process of construction of the professional identity of the future Physics teacher educator, which is made up of her identity as a researcher and a Physics teacher. In the construction of her identity as a researcher, the thoughts of Paulo Freire appear in the reflection on the professional identity that is built from life history and knowledge to build autonomy: *[...] I keep thinking that it is impossible for a teacher to have this autonomous professional identity without taking into account the collective, because the professional identity is individual and collective. [...] This knowledge is also built collectively on the school floor, with its trainers, colleagues, school management [...].*

The construction of identity as an educator is woven into the dialectical understanding of the formative process between the subjects and in the critical review of the difficulties in the pre-service Physics teacher education, including disciplinary formation in Physics: *[...] Physics is culture, and the role of Physics in society is to provide subsidies for citizens to critically reflect on Science, on technology, [...] so that you understand the role of this science today, especially now that we are living in a pandemic context and with the resurgence of scientific denial, for example, with the president of Brazil indicating the non-use of masks.*

Finally, the Life Story is amalgamated to her understanding of the world and her professional work: *I think that this hope to fight, comes especially from the context of my life story and the historical context in which I emerged [...] A phrase by Paulo Freire that I always remember, when he dedicates the Pedagogy of the Oppressed, he speaks like this -For the ragged of the world, who like me, meet, and when they meet, they suffer, but above all for them they fight, so I consider myself that person, the ragged of the world, and I'm going to fight for the ragged ones in the world, who were forgotten.*

4 Final considerations

The discourses show that professional identity is being consolidated in the confluence of reflections on what it means to teach and learn physics, which complicate the representation from physics teacher, through researcher, to physics teacher educator, and her life history, which is questioned by the ideology and the conditions of production, present in each of the re-significations. Thus, physics teacher education is inscribed in hope and love as understanding of the other, as attentive listening and fighting for social transformation.

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Parallel 7 - Wroclaw / 125

Design and development of a new measure for the assessment of the students' engagement in physics extracurricular activities: the Physics Engagement Evaluation Scale

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We present a new instrument, the Physics Engagement Evaluation Scale (PEES) for the evaluation of the students' participation in physics extracurricular activities. The questionnaire was administered to about 300 secondary school students who participated in the activities of the Scientific Degrees Plan in Physics. The instrument shows a four-dimensional factor structure: *satisfaction towards the activities, value of the activities, difficulty in following the activities; involvement of family in the activities.* Possible uses of the PEES include evaluation of outreach activities in physics.

Parallel 9 - Hanoi / 126

Preparation of an experiment tool for energy conversion to be used in high school physics classes

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Lack of interests for learning physics has become a major problem in recent Japanese science education. It has been often said that actual experiences of physics phenomena through experiments will be effective for attracting or stitumating students' interests towards learning physics. However, in present actual situations of high school education scene, experiments are not sifficiently conducted in daily classes.
From another perspective, the research results by American National Training Institute indicate that learning retention rates can be expressed in the form of a learning pyramid, and conventional classroom-style lectures exhibit the lowest effectiveness. The learning pyramid model indicates that the learning retention rates can increase when more actual activities and teaching experiences are involved.
In view of the above background situations, in this study, Joule's experiment, which converts mechanical energy into thermal energy, was picked up, as one of experiments that are not likely to be actually conducted in classrooms although being famous and found in textbooks. An experiment tool for realizing the Joule's experiment was provided for allowing to actually experience the energy conversion. About 10 minutes work with the tool realized certain temperature rise.

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Students’ Reasoning while Using Mathematics in Physics Lessons

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The interrelationships between mathematics and physics in the context of teaching and learning physics are attributed in the literature to a distinct domain (hereinafter referred to as “Physmatics”) that encopmasses unique skills and modes of thinking. Students are known to exhibit difficulties with respect to this domain. In this study we analyzed videotaped lessons in order to identify, classify and categorize indications of such difficulties among high school students, and, in parallel, physics teachers physmatic skills during teaching. Our analysis resulted with two categorization systems: one is based on existing models and one constructed bottom-up. We conclude with insights into how this double categorization will contribute to better instruction

Parallel 10 - Wroclaw / 128

The Second Quantum Revolution at school: teaching and learning Quantum Physics in the context of Quantum Technologies

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The context of the Second Quantum Revolution, in which basic results of Quantum Physics are generating new technological applications, is exploited to devise teaching-learning paths for high-school teachers and students. The concepts of quantum state, superposition, entanglement and measurement are addressed introducing the qubit and the quantum logic gates.

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Development of a New Study Module about Knowledge Acquisition in Science

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At the Technical University of Darmstadt, the pre-service teacher study curriculum was restructured as part of the MINTplus2 (engl. STEMplus2) project. An important goal of the new curriculum is to improve the STEM education of future teachers and thus the STEM teaching in German schools. In this contribution, a new study module of the new curriculum is presented in which pre-service teacher students deal with the acquisition of scientific knowledge. The module was evaluated with a pre-post test to measure how attitudes towards scientific knowledge generation have changed.

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T3ki Mars-rover in physics class - STEM project for high school students

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Abstract. The following paper present a school project which helps to combine theoretical knowledge and students' brainstorming and engineering skills in a STEM activity. The topic is applied in the classroom through inquiry- and project-based teaching methods, and in the Science Club activity. The goal is to develop students' competencies in such a way that is attractive and fascinating for them. It is also excellent for physics classes where certain chapters of mechanics, optics or electromagnetic waves are taught, as it connects the observations and laws of different phenomena to accomplish the tasks at a wider level than in the curriculum.

1 Introduction
Introducing the matter of space research at the high school level is not an easy job for the teacher, because even those students interested in this topic do not necessarily hold enough patience to investigate alone and thoroughly the theoretical background, and thus their lack of academic knowledge (regarding mathematics, physics, or computer science) results in not being able to understand subjects related to space exploration. Therefore, these deficits need to be bridged by the teacher who initiates the display of an issue similar to this one. In this case, the relevant ESA - ESERO projects and their applications in the given school context could be a good help. The main target of students is to build a controllable rover (the one that is used to discover the surface of the planet, Mars), a robot capable of exploring an unknown area, performing special measurements, and transmitting the obtained data to the control centre.
The teaching method used in the implementation of the project is based on the 4Cs (creativity, critical thinking, communication, and collaboration) principle, serving as the foundation of the active learning strategies. Classes are built in a way to provide a flipped classroom, a peer instruction session, problem solving tasks, and many hands-on activities. The teacher does not act as a source or transmitter of information, but rather as a mentor and facilitator, who supports each group allowing them to work in their own rhythm (according to students' personal abilities, skills) in developing, understanding, and demonstrating the topic.
2 T3ki Mars-rover project
The major stages of the project are the followings: making the design of the rover, writing the rover motion control programs, designing and developing hypothetical foundation of the measurement tasks (design of the electrical circuits), construction of the rover and coordination of individual modules, and of course, the testing.
In the design phase, students apply their computer skills and use C ++ learned in school to write test programs. During the time of the teamwork, they become familiar with the Python language. A special microcontroller unit needs to be built into the rover's remote-control panel and data transmission unit, followed by an easy-to-use control device. Samples, images, and data collected from the unknown area are saved by the rover to an SD card. Returned to the control centre, the data is processed and displayed on a webpage.

Fig. 1 The T3ki Mars-rover
The project is very complex, takes up a lot of time and effort, but is very popular among students because of the many entertaining and challenging activities. They have the possibility to constantly test new ideas to improve the movement, control, or data processing of the unit which in the long run helps them learn new skills and improve existing abilities.
3 Conclusion
The building of the T3ki-rovers provides a non-traditional learning opportunity for high-school students to work freely on their own, giving rein to their ingenuity, but at the same time keep deadlines and follow the rules. The teacher can observe how the acquired knowledge is utilized, how the young people have become more confident in working the tasks out, and how the created rover - the end-product – becomes more and more efficient and reliable day by day. Although, more males are involved in IT projects, some female students find the building of the Mars-rovers exciting, as well.

They could also easily find creative objectives and achieve success in this field.
The experience has shown that students who are involved in solving such tasks for at least one academic year are more confident in their career choices, mostly in technical, IT-based undergraduate studies. These students are more open to technical innovations, easily engage in managing highly challenging problems, have advanced critical thinking, and are more inventive.

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Parallel 8 - Wroclaw/Guayaquil / 131

Eye-Tracking Based Evaluation of Experimental Problem-Solving in Mixed Reality Learning Environments

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Abstract. Mixed reality (MR) is playing an increasingly important role in teaching and learning natural sciences, as it can support learners especially during experimentation. We investigate the support with MR in experimental problem solving and use the probands' gaze data for a more detailed analysis. It is shown that experimental problem-solving success increases with the support of MR, especially for novices, and that this is accompanied by a significant shift of visual attention. Furthermore, it can be shown that novices can be supported with MR in such a way that they proceed more like experts during experimental problem solving.

1 Introduction
In recent years, mixed reality (MR) has become increasingly popular in science education [1, 2], as it opens up new opportunities that would otherwise not be possible. In physics education, MR can support experimentation by simultaneously displaying additional information related to the experiment and actual measurement data. The most comprehensive possibilities are offered by MR Head-Mounted Displays (HMDs) as they can not only superimpose virtual elements, but rather integrate them into real space. Another advantage of HMD is to be hands-free during experimentation as compared to tablet-based augmented reality. Recent studies have shown that the use of MR has a positive impact on conceptual knowledge as well procedural tasks [3–6].
Current HMDs are equipped with eye-tracking technology, providing built-in possibilities to evaluate MR applications based on visual attention and gaze patterns. Eye-tracking based evaluations are often used for usability evaluation studies in the context of human-computer interaction, but also in physics education in relation to problem solving or the use of multiple representations in reasoning

[7–9].
The approach to experimental problem solving often differs completely between novices and experts. This is partly due to prior procedural knowledge in scientific work, but to a large amount it is also due to prior subject specific knowledge and the use of visual and mental representations [10]. Experts generally take their time in the beginning to form representations, while novices tend to rush through this phase and usually use more naive representations. MR can assist with experiment-specific representations to enhance prior knowledge and provide novices with similar opportunities as experts for subsequent problem solving.

Fig. 1 (a) Experimental setup and (b) MR learning environment

2 Experiment and Evaluation
For our study, we have chosen an electrical circuit with a certain complexity, so that neither experts nor novices will know how to solve the problem right away (s. Fig 1a). Participants are asked to first understand the circuit and then to maximize the time between the lighting of two lamps with additional cicuit modules. Based on the approaches of experts and novices, particularly their eye-tracking data, an MR application was created to best support the novices in problem solving on the experiment. In the MR learning environment (MRLE), representations such as the electron flow and the capacitor charge are visualized (s. Fig 1b). In the second part of our study, the experiment was performed by additional participants with the support of this MRLE.
For the study the participants were divided into two groups, one with high prior knowledge and one with low prior knowledge, on the basis of a subject-specific questionnaire. Subsequently, eye-tracking data was recorded during the experimental problem-solving process and additionally, self-reported cognitive load was collected questionnaire-based. Finally, semi-structured interviews were conducted. In addition, problem solving success was analyzed based on the experimental outcome.
The analysis shows that both novices and experts achieved a higher problem-solving success in the MRLE than the subjects without using MR. The visual attention of experts and noivces both with and without MR were analyzed and compared quantitatively to each other for selected areas of interest. It is shown that the improvement in problem-solving success using the MRLE is accompanied by a significant shift in visual attention for novices.

3 Conclusion and Outlook
The MRLE has resulted in novices applying expert-like strategies in problem solving based on their gaze data. Therefore, we propose to use MRLE supportively in experimental problem solving to direct visual attention in ways that enable novices to be more successful. Furthermore, eye-tracking data should be analyzed to gain insights into the effects of design considerations and visualisations, and to incorporate the results into the further development of MRLE.

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Parallel 10 - Wroclaw / 132

Didactics for Contemporary physics and modern physics teaching at Strathmore University (Nairobi-Kenya)

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The abstract gives the overview of the good practise being used at Strathmore University and university of Palermo in delivering contemporary and modern physics education to the students of B.Sc. Electrical and Electronics Engineering. The method which deploys more of didactics than calculatory involves students engaging with each other in investigating the phenomenon and presenting the findings from the investigation. The methods makes students more interactive which eventually improves on their communication skills as well as team work.

Parallel 8 - Wroclaw/Guayaquil / 133

Traditional and Innovative physics teaching approaches: a social representation study

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Abstract. In this work we investigate social representations from a group of physics teachers in training (N = 98) regarding traditional and innovative teaching approaches, combining complex network analysis and a likert questionnaire. Our results show representations on traditional approaches more related to pragmatic classes' material and innovative approaches represented focused on experiments. That indicates a reproduction of a well structured teaching culture in formal institutions.

`1 Introduction`

It is perceived from physics teachers that there is an established tradition in classrooms and school systems set to keep its own survival [1]. During their training, pre-service physics teachers form consensual views on both traditional and innovative approaches, producing social representations (SR) [2] on that. By exploring SR it is possible to get insights for rethink training strategies, at the institutional level. In this work we aim to investigate SR on traditional and innovative physics teaching approach from pre-service physics teachers in a public university in Brazil and its possible relation to implementations of both on their future teaching career.

`2 Theoretical framework`

The SR theory was proposed for exploring group's ideas and visions. SR are a phenomenon by which social reality is created anchoring and objectifying knowledge objects, converting the "unfamiliar" into familiar. It allows one to forms stable consensus, which can give identity to a group, helping to deal with life demands. Regarding its structure, SR can be both stable and dynamic, at the same time, differing nuclear and peripheral elements [3]. Lexical relational structures can be represented as complex word networks, revealing possible nuclear and periphery in the structure [4].

3 Methodology

The study toke place in a Brazilian public university in São Paulo state. A group of 98 undergrad physics teacher in training was inquired during the 2017/2018 school year. Two research instrument was used: (a) a ten items likert-questionnaire regarding innovative/traditional approaches and (b) two word similarity networks taking from each student the first 5 evoked words regarding each teaching approach. Internal consistency indicators were computed. The data was processed using R [5] and specific packages.

4 Results and brief dicussion

For the likert items, internal consistences were ω = .709 and α = .607 (Fig. 1, A). The network for "traditional" (Fig. 1, B) has 61 lexems with 296 relations. The terms blackboard, chalk and exercises indicate a central core anchored in classroom pragmatics. The "innovative" network (Fig. 1, C) showed 74 lexems with 303 relations, centered in the idea of experiments and dialogical aspects. [see Figure 1 in the attached PDF] It may be contradictory that a traditional aspect of physics, such as experiments, is recognized as innovative. At the same time, monological classes make a strong sense of tradition. Meanwhile debate and discussion, even though being a form of teaching since the firs humans, is represented as innovative.

5 Final Considerations

Central core elements of a SR, are stable and resistant do changes. As pre-service teacher focus on traditional assumptions of what would be innovative, university curricula are demanded to consider students consensual world in order to be effective.

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Parallel 8 - Wroclaw/Guayaquil / 134

University course in experimental physics at home: possibilities and practices

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Abstract. In this work we report the implementation of an experimental physics course in emergency distance education format. The structure used for the course is presented and a theoretical framework clarifies the engagement aspects of the course, marked by digital inequality in a developing country.

1 Introduction

The COVID-19 pandemic have accelerated the remote education in all levels, worldwide [1]. The so-called emergency remote education (ERE) became for the past 1½ years the mainstream of educational systems in several countries. Specially for developing countries, that made explicit students' digital inequality and the lack of proper institutions infrastructure [2], affecting attempts to keep educational systems to keep running during the pandemic.
At university level, ERE brought up challenging demands of all sorts. Regarding experimental physics courses, adaptations for implementing ERE format required have been reported [3]. In ERE format students faced the need for setting up at home activities and experiments that would be traditionally set in physics lab. Considering those who were earning teaching credentials in physics, another aspect became salient: beyond to set up sort of a lab at home, the whole idea of physics concepts learning through experiments demanded a reconsideration.
In this work our aim is to report and analyze solutions for an experimental physics course in a public university in Brazil under ERE format, contrasting possibilities caveats implicated in this approach.

2 Conceptual framework

In the experiments, we followed problem-solving structure [4] and we set the activities oriented by the team-based approach recently brought to physics education [5]. Also, in order to make the the experiments engaging for students, we draw on engagement theory [6], offering in each experiment (i) a clear set of rules, orienting students; (ii) room for self expression, as students could adapt their experimental setup and (iii) allowing students to have enough feedback for keep tracking their own progress.

3 Teaching and learning structure and context

The Experimental Physics I course was conducted by 4 university professors with nearly 100 grad students attending it each semester. It mixes synchronic/a-synchronic activities. Students were encouraged to use material that can be found in daily activities (Fig. 1) [See Figure 01 in PDF attached]. Six experiments on classic mechanics were proposed, varying from newton's second law to motion under drag forces. Working in groups of three, students are furnished with previous instructions videos, advising on experiments assembly and about data collecting and analysis. Then, students toke a set of conceptual tests on the physics specific content regarding the experiment. After that they are suggested to gather the material for assembling the experiment.Thus, they perform the data collection for proceeding the analysis which ends up in a scientific-like report. Students lacking the technical apparatus (like not having a computer, a smartphone or so) got from university a budget of 1½ Brazilian minimum wage overcoming digital inequality [7].

4 Final Considerations

The ERE experience in experimental physics changed deeply the teaching dynamic in the physics department. With nearly a hundred students finishing the course during the 2021/1 semester and another hundred enrolled for the 2021/2, it can be said that structuring the course for proceeding experiments at home helped to overcome some of the challenges COVID-19 pandemic have imposed. As pandemic is still on, ERE format may be the only way to go, even in experimental physics coursed. Our approach showed (a) it is feasible to proceed a lab course at home; (b) experiments must be adapted for that; (c) minimizing the digital inequality is mandatory and (d) although difficulties on specific content seems to be the same as in loco lab classes, by providing cycles of online feedback, students had more opportunity to overcome their obstacles.

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Parallel 10 - Wroclaw / 135

State of the art of the sum over paths approach in quantum mechanics education

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Abstract. In this contribution I present an overview of the history and recent developments of the Feynman sum over paths approach for teaching introductory quantum mechanics to high school students and University undergraduates. It is argued that sum over paths has now reached full maturity as an educational reconstruction of quantum physics, and offers several advantages with respect to other approaches in terms of leading students to develop consistent mental models of quantum objects and ultimately achieving better conceptual understanding.

1 Introduction
The sum over paths approach in physics education originates mainly from two sources: Feynman's path integral formulation of quantum physics [1] and his own divulgation book "QED: the strange theory of light and matter" [2]. The latter, in fact, constitutes the first, fundamental sketch of an educational reconstruction of quantum physics based on the path integral formulation. Among the milestones of the approachs' development one can trace the undergraduate course on quantum physics "Demistifying quantum mechanics" held by E. F. Taylor at MIT [3] which had a profound impact in the international physics education research community; and the Advancing Physics project [4] of the British Institute of Physics, an advanced physics course for high schools, designed to attract students to physics, and to give them a good basis for their future progression in the subject at university level, in which J. Ogborn, A. Dobson and co-workers [5] proposed an innovative presentation of quantum physics based on sum over paths. After the turn of the millennium, interest on the sum over paths approach has grown, with several works of great interest, both empirical [6,7] and theoretical [8,9].

2 Recent developments
Recent educational research has addressed most of the open issues standing on the sum over paths approach, including devising effective educational strategies for discussing time-independent problems such as bound states and tunneling [10, 11]; improving the treatment of the uncertainty principle [11]; establishing connections with two state approaches based on spin or polarization [12]; designing and realizing tools, such as interactive simulations and tutorials, to sustain students' learning [13, 14]; pinpointing and clarifying the educational advantages of sum over paths, including reliable measures of conceptual learning outcomes [15, 16] and highlighting the importance of concepts, such as path distinguishability, which were not central in the initial educational tests of the approach, but have demonstrated extremely fecund in leading to conceptual understanding of wave particle duality, and allowing to introduce modern experimental settings and technologies [17].

3 Educational advantages
Based on the results of research literature, and several years of direct experience with using the sum over paths approach in teacher education, we can summarize the main educational advantages offered by the approach in the following way:
• On the mathematical level, the sum over paths approach allows to discuss quantum phenomena using a very simple formal language. At its heart, such possibility is due to the fact that, rather than finding solutions to the Schrödinger equation, Feynman's method constructs the Green function for the same equation, representing it as a sum of complex amplitudes computed over all possible paths. In educational practice, complex amplitudes associated to paths can be represented and added up as vectors or "little arrows", a strategy directly derived from the one used by Feynman himself, which greatly reduces the stress on student's cognitive resources while learning the basics of quantum theory.
• On the conceptual level, sum over paths has the unique peculiarity of offering students a very clear and unambiguous representation of one of the most profound quantum mysteries, namely wave particle duality. The central distinction between classical and quantum ways of computing probabilities, which is at the heart of the approach, allows both to clearly distinguish classical and quantum physics, and to make the classical limit (correspondence principle) completely transparent. Furthermore, modern educational reconstructions based on sum over paths can offer deep insight on the

origin of energy quantization for bound systems, help clarifying the meaning of the uncertainty principle, and pinpointing the siimilarities and differences in the quantum behaviour of photons and electrons. Finally, sum over paths, with the introduction of the idea of path distinguishability/indistinguishability, allows to construct a language capable to discuss modern experiments and technologies based on quantum optics.

4 Conclusions
In my overview of research on the sum over paths approach for teaching introductory quantum physics, I argue that such approach, started in the late 1980's, has reached full maturity in the second decade of the XXI century. Based on its characteristics, sum over paths can help researchers and educators improve educational outcomes in terms of conceptual understanding, and be an invaluable aid in the introduction of quantum technologies, an issue which is increasingly felt as central and urgent.

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Parallel 2 - Wroclaw/Guayaquil / 136

Investigating the relationships between gender stereotypes, dis-

ciplinary identity and academic performance

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Abstract. The Gender stereotypes, Disciplinary Identity and academic performance (GEDI) will be presented. This project aims to analyse the role of gender stereotypes in conditioning the construction of disciplinary identity, i.e. the ability to identify oneself with the discipline and to have science career aspirations in the same area, of STEM students.

1. The GEDI Project's Objectives
   The role that society attributes to people, on the basis of their gender characteristics, affects their personal life, educational choices and work experience. This mechanism often limits personal and professional fulfilment, especially for women, and it can be due to a multiplicity of social, cultural, economic, educational and institutional factors. Although the scientific literature has long shown that men and women possess quite similar skills, methods and general approach to problem solving [1-2], some areas of study and work are absolutelymale dominated, with a greater presence of women in areas with lower employment, career and income prospects [3]. The gender gap is particularly harsh in STEM (Science, Technology, Engineering and Mathematics) fields, and is fuelled by a complex set of gender stereotypes that affect women's interest, self-efficacy and, in turn, their educational and professional choices [4]. To better investigate gender gap in STEM, the GEDI project aims at validating a structural model of disciplinary identity, including gender stereotypes as precursors and psychological and metacognitive variables – interest, sense of belonging, perceived utility, confidence and self-efficacy – as relevant mediators, which in turn can also influence persistence in choosing a career in STEM. The specific objectives will be: (i) to explore a possible relationship between gender stereotypes and interest, confidence, sense of belonging, perceived utility, self-efficacy and disciplinary identity in students enrolled in the first year of university; (ii) to explore the complex relationship between the variables studied and academic outcomes; (iii) to monitor the evolution of these relationships over academic years.

2. Sample and methods
   To answer our research questions, about 1000 students attending different undergraduate STEM courses will be involved. To study the evolution of disciplinary identity, students from three university cohorts will be involved: first, second and third year. In addition, non-STEM students will also be involved to investigate differences due to gender stereotypes. The instruments used for this study will consist of a battery of instruments: (i) personal data survey (age, gender, geographical origin, political and religious orientation, type of diploma, socio-cultural capital); (ii) Ambivalent Sexism Inventory and Male Role Norm Scale; (iii) interest, perceived utility value of the course of study, sense of belonging, confidence and disciplinary identity; (iv) perceived self-efficacy in the discipline. University performance will be assessed using the obtained ECTS. The measurement model will be tested using confirmative factor analysis (CFA). To assess the differences between female students and male students and between different students' groups (STEM and non-STEM), a multi-group structural analysis will be carried out.

3. Expected results and dissemination The theoretical framework that will be validated in this project will not only contribute to the current knowledge of the construct of disciplinary identity in STEM, identifying significant precursors and mediators, but will also improve the current knowledge of the relationship between disciplinary identity, performance and academic persistence in STEM. Based on the expected results, it will be possible to develop interventions aimed at promoting STEM education and more gender-inclusive STEM careers in secondary schools and universities, in particular by addressing the role of gender stereotypes in order to build a more autonomous and conscious disciplinary identity.

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Parallel 9 - Hanoi / 137

Pedagogical beliefs of South African physics teachers for inquiry approaches

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This study investigated the relationship between the pedagogical beliefs of South African physics teachers and their preferred instructional approaches to inquiry. A key curriculum goal in school science education in many countries is inquiry-based learning. The results of a quantitative survey that was administered to 163 teachers revealed there was an association between the pedagogical beliefs of teachers and their preferred instruction approaches. With regards to teachers who perceived themselves as having constructivist pedagogical beliefs, there was a strong positive association between such beliefs and their preference for guided inquiry and open inquiry.

Plenary 6 - Hanoi/Wroclaw / 138

Symposium on Teaching and Learning Quantum Physics

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Quantum physics and its implications for future science and technology is becoming culturally important and more attention is being given to its introduction before university level.
There is a rich literature about different approaches and strategies [2]: 1) historico-philosophical, 2) matter-wave, 3) two-state systems, 4) Feynman path integrals, 5) quantum field theory, 6) quantum technology, which have been all adapted for pre-university level. Further differences are in: a) contextual aspects: e. g. choosing a spin, polarization or double well two-state system, and b) methodological aspects, using frontal traditional presentation or active engagement methods. All approaches show learning gains among students.
Given the diversity of approaches, there are growing efforts [3] to identify key concepts to be taught and key competences to be learned hinting that all approaches might not be equally suitable to introduce different concepts. The symposium gathers experts who have experience in teaching quantum physics with some of these approaches in different settings and with different populations to share their experience and insights into the advantages and potential limitations of the various presented approaches.

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This symposium is sponsored by the GIREP Thematic Group "Teaching/Learning Quantum Physics" in view of its interest in knowing and discussing promising strategies to produce innovative quality and integration of proposals for teaching/learning quantum physics.

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Parallel 1 - Wroclaw / 139

Pre-service physics teachers' practical training under pandemic restrictions

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Abstract. The paper presents challenges caused by COVID-19 pandemic situation and lockdowns of pre-service teachers' practical training between March 2020 and May 2021. The standard structure of practical training is introduced and the impact of pandemic restrictions on practical training from pre-service teachers' and supervising teachers' views are described. Suggestions for future design of practical training are formulated.
1 Introduction
Practical training of pre-service teachers is crucial part of their professional identity development [1]. Pre-service physics teachers undergo their practical training at lower and upper secondary schools under the supervision of experienced physics teachers. Students of the Faculty of mathematics, physics and informatics, Comenius University in Bratislava (FMPhI CU) complete their training in Bratislava, regardless of which part of Slovakia they come from. The training consists of three parts as characterized in Tab.1., terms are fixed in the Study schedule.

Table 1. Standard structure of pre-service physics teachers' practical training FMPhI CU
Practical training Phase of the study Duration and term of the practical training Form of the training
Part I. 3rd year
of bachelor study 1 week (April) Observation, 2x micro-teaching (short teaching episode), analysis of lessons with supervising teacher
Part II. 1st year
of master study 2 weeks (February-March) Observation, 2x micro-teaching, teaching 4 complete lessons, analysis of lessons with supervising teacher
Part III. 2nd year
of master study 3 weeks (September – October) Observation, teaching 12 complete lessons (at least 8 different), analysis of lessons with supervising teacher

2 Organizing practical training under pandemic restrictions
The main problem in organizing the practical training in March 2020 was the uncertainty of the way schools work. Upper secondary schools in Bratislava region were closed. Lower secondary schools were open, but school-managements feared the health consequences of pre-service teachers' presence in the school and canceled the agreed practical trainings. Therefore, students who had a practical training scheduled for March, completed it in an alternative form under the guidance of a university teacher. From April 2020 schools switched to distance education and the practical training took place online. Several supervising teachers canceled the agreed practical training because they did not feel confident in online teaching. (In general, less than 31% of Slovak teachers felt confident in their own readiness to teach distantly.) Other experienced teachers were contacted instead.
In September 2020, the schools were opened. However, the general closure of schools and the transition to distance education were expected. All pre-service teachers studying at FMPhI CU had their training in face-to-face form at lower secondary schools in their place of residence. In several cases, small size of school caused reduction of lessons completely taught by the pre-service teacher.
From the middle of October schools 2020 switched to distance education again. All pre-service teachers studying at FMPhI CU had their Part I. or Part II. of practical training in distance online form.
3 Pre-service teachers' view
All FMPhI CU students use distance learning in the form of asynchronous supportive courses in the learning management system Moodle and multimedia materials. However, this is not sufficient preparation for full-fledged distance learning, and not at all for effective online teaching. In March 2020 pre-service physics teachers had no experience with online synchronous education.
The pre-service physics teachers were glad that they had practical training at all. Many of them welcomed that they could have training in their place of residence, in schools where they had previously studied, so they were in a familiar environment.
4 Supervising teachers' view
Several teachers canceled the agreed practical training because they did not feel confident in online teaching. Those, who agreed to supervise pre-service teachers, rated the experience positively. Pre-service teachers brought to practice of online physics education some new resources and teaching methods (e.g. simulations, applets and video-measurements), which supervising teachers had not used before. Pre-service teachers were helpful in solving some technical problems and actively contributed to the creation of online learning content.
5 Conclusion
Realization of practical training in familiar environment of a school in students' place of residence is an opportunity to meet pre-service teachers' needs. At the same time, it is a challenge to find inspiring experienced supervising teachers in different regions of the country. Online introductory meeting of the pre-service teacher and the supervising teacher before visiting the school is a new opportunity to improve quality and effectivity of practical training.

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Parallel 10 - Wroclaw / 140

The real medical situation for Physics teaching

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Abstract.
In Italy, there is a module on Applied Physics for the obstetric degree course, including fundamental Physics features: from the theory of measurement to the waves. Here, we propose the planning of a 12-hours module focusing on the Physics of childbirth. Each lesson starts with an engaging, so that students may be involved in a real medical situation, focused on birth. Suddenly, they may explore it and, finally, in the explain phase, main Physics topics related to the proposed situation are discussed and deepened.

1 Introduction

This paper describes a didactic experiment carried out with 60 university students attending the first year of Faculty of Obstetrics of the University of Salerno.Typically, in Italy, the study of Physics is planned in all medical faculties. In Obstetrics, the timing for Physics teaching usually ranges from 12 to 20 hours. The teaching design of the Physics module usually includes the following topics: measurement theory, kinematics, dynamics of material points and extended bodies, fluid dynamics, thermodynamics, waves, and electromagnetism. Methodologically, the subjects are proposed according to a waterfall progression following the schedule by the most typical textbooks, using frontal lessons, due to the program's size compared to the small number of hours. The exam students'results of the last three years, highligt the students' difficulties in dealing with so many topics. Moreover, some students believe Physics topics aren't helpful for their future work. Thus, it was thought to redesign a 12-hours Physics module for the Faculty of Obstetrics, using an active methodology, such as Inquiry [1] in blended mode. The Inquiry includes a situated learning, as a learning in a specific context. Each lesson, lasting about 3 hours, includes the experimentation of some Inquiry phases. In particular, Engage and Explain are present in each meeting, while in 2 sessions, an Explore phase has also been designed. The Extend is carried out for each meeting by sharing multimedia material on a specific platform. On the other hand, the Evaluate consists of the final test. The Inquiry aims to motivate students to study Physics, using real situations in the medical environment, thus trying to decrease the gap between academic culture and real life. The Situated Learning model [2] provides the theoretical framework for the experimentation.

2 Situated learning: from idealized model to real physical situation

Jean Lave and Etienne Wenger [2] proposed the term "situated learning" as a model of learning that takes place in a "community of practice". They argue that learning should not be considered simply as the transmission of abstract and decontextualized knowledge from one individual to another, but as a social process in which knowledge is co-constructed, suggesting that such learning is situated in a specific context and integrated within a particular social and physical environment.

Such approaches' main idea consists of contextualizing subject material because "pure" science is an abstract topic often incompatible with everyday life. It is also permitted that students move from the traditional system of learning to problem-solving. Because of using such a strategy, one can observe growth in students' motivation. The nature of situated learning comes from situated cognition, which accentuates the context in which something is learned, so knowledge forms the part of activity, culture, and life.

3 The activities: blended online and in class-format

The Physics module focuses on the 'Physics of childbirth'. Starting from some real situations concerning the period of gestation and the moment of the birthing, it is possible to connect some of the related Physics topics. For istance, blood test reading can be the starting point for the study of measurement units and errors. Furthermore, the principles of dynamics could be used for a better comprehension of the chidbirth. Nevertheless, the reading of an ultrasound scan can be the starting point for a lesson on waves and some elements of electromagnetism.

The teaching has been "blended" based on the integration of frontal lessons, Peer Discussion and E-learning, also carried out using the educational platform.

4 Research Methodology

A multimethod methodology collects research data by analyzing the answers to a questionnaire given to students based on the Likert scale [3] and open-ended questions. The questions are aimed to investigate the parameters of students' engagement, motivation, and participation [4]. The comparison between the final exam results with those of the students of the previous two years completes the quantitative analysis of the research data.

5 Conclusion

Here we planned and experimented a Physics module for 60 Obstetrics students, based on an active methodology, the Inquiry, mainly higlightning the relevance of the situated learning in a medical environment. The thread was the Physics of childbirth". Since the analysis of the protocols, the students feels more confident with Physics and they wondered that some Physics topics are so much fundamental in their future work field.

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Parallel 7 - Wroclaw / 141

Analysis of saccadic movements of students solving problems with graphs in physics

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Abstract.
23 high school students were eyetracked when solving physics problems with graphs. We analyzed their saccades (length, direction). We did not observe differences between correct and incorrect solvers. Some pupils (correct or incorrect solvers) showed a high similarity of saccade directions for the beginning and for the total viewing time, some not.

1 Introduction
The paper focuses on the students graphing in physics. Several typical problems of students graphing, e.g. graph as picture, were identified [1], [2]. The use of the eyetracking method is proving to be beneficial, where we use it to estimate students' cognitive processes when solving problems. Most studies in PER has focused on differences in fixations distribution between correct and incorrect solvers. Klein et al. also focused on students saccades when viewing the vector field diagrams [3].
A graph is a complex abstract representation, but one that at first glance looks like a picture. The eye movements of students who exhibit low prior graphing knowledge might show tracking of the graph curve, aimless graph viewing, etc. Our research questions were: are there differences in the saccades of correctly and incorrectly answering students when solving physics problems with graphs? Particularly, in the length of saccades and in the saccades directions (during the overall time and during the very beginning)?

2 Methods
23 high school students solved 7 problems with realistic graphs from mechanics with a more complex curve shape. Students were eyetracked (TobiiTX300) while viewing the graphs. We then recorded their verbal response and the students proceeded to solve the next task. After the experiment, we reviewed the record with them and they completed an additional questionnaire about their attitudes towards science.

3 Results
Tab. 1 shows the number of correctly and incorrectly answering students. The seventh problem was very difficult; we did not analyse this task. Further, Tab. 1 shows the average length of the saccades. The data suggest that there are no differences between the two groups.

Tab. 1 Average length of saccades of correctly and incorrectly answering students.

We plotted the direction of saccades for each participant and each task on a polar graph (Fig. 1). We displayed the data for the total viewing time and for the first 40 saccades (approx.10s). We performed a qualitative comparison of the graphs between correct and incorrect solvers. No differences were identified. Some pupils showed a high similarity of saccade directions for the beginning and for the total viewing time (Fig. 1), some not. Both of these groups of students were present among both correct and incorrect solvers.

(a) (b)
Fig. 1 Direction of saccades – a participant and one task.
(a) For the total viewing time, (b) for the first 40 saccades.

4 Conclusion
Differences in the distribution of fixations between correct and incorrect solvers have been identified in many previous studies. We did not observe differences in the case of saccades (length, direction). Some pupils (correct or incorrect solvers) showed a high similarity of saccade directions for the beginning of viewing and during the total time, some not.

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Parallel 8 - Wroclaw/Guayaquil / 142

Kinematics of a bicycle with Phyphox

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Abstract. Currently, the use of bicycles within the university campus is very common and it is an opportunity to teach our students the kinematics by studying the movement of the bicycle. For this purpose, we used the 3D point position GPS locator, an application of Phyphox a free software for smartphone. The smartphone with this application was attached to the bike to measure its movement while a person rides it on any road. In this work we discuss the process that its follows to study the concepts of kinematics when they ride a bike with the GPS tracker.

1 Introduction
Classical mechanics is generally taught to university physics students in their first year of university. It begins with kinematics where important concepts that describe the motion of a particle are introduced. Kinematics is often referred to as the geometry of motion [1] and is taken as a branch of mathematics.
This mathematical approach to motion is difficult for students to understand when they experiment with motion phenomena in the laboratory and even more so when these phenomena refer to mobiles of everyday reality that must be described according to the concepts of theoretical kinematics.
To overcome this difficulty in understanding students, we set out to teach kinematics by studying the movement of the bicycle.
2 Motion of a bicycle
In our university, as in many other universities in the world, the free use of bicycles has been promoted among students as a means of internal transport within the university campus and for students to become aware of its environmental impact. We have seen this as an opportunity to teach kinematics outside of the laboratory with the movement of a bicycle.
For this purpose, we used Phyphox[2] smartphone apps of a GPS locator to measure the position of a mobile on any outdoor road. With the smartphone fixed on the bicycle, the GPS sensor measure the movement of the bicycle as a real situation.
The Phyphox-GPS locator, measures the latitude, longitude and height of the position of a mobile every 1 s and saves the data in a spreadsheet that it is used to analyze data.
We collected data with this motion sensor in a closed circuit of the parking lot of our School and we have analyzed the data in a spreadsheet that was imported into Google Earth software for showing of the movement in the same real scene where the movement occurred (Fig. 1).

Fig. 1 A view of the movement of the bicycle in a closed circuit on the parking lot of the Science School.
3 Analysis of the movement.
The data analysis begins with the graph of the motion path and the graphs of the x and y coordinates as a function of time (Fig. 2a and 2b). In this analysis, we make a translation of the geographic coordinates of latitude and longitude to a local XY-system, measured in meters, originating at the beginning of the movement.

Fig. 2 Graphs of the movement of the bicycle. (a) trayectory of the motion, (b) x(t) and y(t) and (c) a straight line motion at constant speed.

Figure 2c shows a part of the motion of the bicycle at constant speed with v = (0.64, 0.50) m/s and 1v1 = 0.81 m/s.
4 Conclusion
The study of the kinematics in an outdoor activity of the movement of a person on a bicycle allows students to establish the relationship between theoretical concepts with reality, because at the same time, they are observers and subjects of experimentation. This dual role establishes a strong mental connection between the experienced and the conceptualized that helps students build better knowledge.

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Parallel 8 - Wroclaw/Guayaquil / 143

Reflections about Nature of Science in Physics Teacher Training

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Reflections about Nature of Science in Physics Teacher Training
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Abstract. This work aims to present a paper review in international journals about the nature of science in physics teacher training, analyzing two categories: keywords and research characterization. The papers analyzed allow us to state that there is a trend in research on the nature of science in teacher education regarding contextual and methodological aspects.
1. Research
Our aim in this research was to present a paper review in international journals about the nature of science (NOS) in physics teacher training. Therefore, based on a process of searching and selecting papers in a specific journal portal [1], we analyzed 26 papers of different nationalities published in international journals in terms of two categories. The categories keywords and research characterization generated a more in-depth discussion, aiming to obtain a manifestation by researchers in the area of how research using the NOS for Teacher Education in an international context is carried out. Using qualitative data analysis software [2] and making use of Content Analysis [3], each paper was coded according to two categories, culminating in other subcategories, which sought to deepen the understanding of the plurality of contexts and how research is carried out in this field of knowledge around the world. Thus, since this is a state of knowledge survey [4], quantitative and qualitative data were obtained, which refer, for example, to the characterizations of the sample group of this research, through the analysis of the most eminent justifications for the use of NOS and the main teaching and research methodologies used, as well as the perception of which contexts receive this researches.

2. Results
From 26 papers, only 14 (53.8%) presented keywords in the abstracts. In the analysis, we identified 66 keywords that formed 8 subcategories: nature of science; teaching/education in science and nature of science; teacher training; context of teachers' performance; teaching and learning methodologies; research instruments and research methodologies; pedagogical knowledge content; and others. The most frequent keywords were related to the 'nature of science' and 'teacher education'. The 'nature of science' subcategory is composed of keywords that refer to the debate on epistemological aspects of scientific knowledge and 13 papers (92.9%) mention the term to synthesize the central ideas of the text. The subcategory 'teacher training' is present in all articles (100%) and is composed of keywords that refer to teacher training in different contexts, whether in initial training, continuing education or complementary, or refer to teacher training in a more general way.
The research characterization category aimed to identify, in each paper, the nature and scope of each research carried out, the instruments used, the application and analysis methodologies adopted, and the research development contexts. Most of the papers were categorized as qualitative research (73.1%) that aim to understand, describe, classify and explain existing relations between the variables found in the research. The other part of the paper is of a quali-quantitative nature (26.9%) that combine qualitative research with some collection and analysis of numerical data. The predominant instruments for conducting the surveys were questionnaires (80.8%) and interviews (65.4%), followed by materials produced by the research subjects (38.5%), the use of dairy board (19.5%) and video recordings (19.5%) and classroom observation (11.5%). Most papers carry out research using more than one data research instrument, and thus involving, in different degrees and methods, some type of triangulation. Research focuses were coded into three subcategories. The first consists of those in which scope is to develop and apply a model for assessment of didactic proposals or participants' knowledge about the NOS, whether they are teachers in training, experienced teachers or even evaluating changes in these conceptions during an applied course (73.1%). The second consists of those in which scope is to elaborate and analyze a didactic proposal intervention with research subjects after a period of studies and appropriation of aspects of the NOS (23.1%). The third consists of those in which scope is to use the history of science to teach about the NOS (3.8%). We analyzed the research application context presented in the papers, both concerning the environment in which they were carried out, as well as the group of participants involved. The research proposals were developed in complementary or continuing education courses such as postgraduate and extra courses (65.4%), in subjects of an initial training course in the general sciences or physics (23.1%), or with groups of in-service teachers, but do not participate in any specific complementary course (11.5%). Out of the 26 articles, most explain analysis methodologies in their investigations (65.4%), and some of these studies have more than one analysis methodologies. A smaller part of the papers (34.6%) did not present elements that allowed them to be classified with some standardized analysis methodology. However, the analysis we carried out allows us to state that these investigations, despite not specifying a standard analysis methodology, develop a kind of interpretative analysis in their research.
3. Conclusions
In summary, the papers analyzed allow us to state that there is a trend in research on the NOS in teacher education regarding contextual and methodological aspects. The papers present qualitative or quali-quantitative research, the scope of the papers is the application and development of didactic proposals for teaching the NOS in teacher education, the papers tend to use questionnaires and interviews as research instruments and value data triangulation.
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Eye-tracking indicators relevant in education and their interpretations

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Eye-tracking indicators relevant in education and their interpretations

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Abstract. Based on eye movements we identified thirty indicators of cognitive processes, that could be applied in education research and education itself. We sorted these and added possible interpretations. Five of the indicators were then applied to data to test their practical usability.

1 Motivation and goals

Eye-tracking allows us to track the movements of eyes, for example when students are reading on a PC screen. Its most important benefit for education is enabling a certain insight into cognitive processing of tested material. This method has been applied in science education before (e.g. [1]), mainly while studying problem solving or reading graphs. Our focus was reading of a specialized text. We wanted to create a list of useable indicators and their possible interpretations.

These could allow teachers to review student's strategies while studying, monitor which part of solving a problem was problematic for a class, or help students by enabling creation of intelligent and highly individualised textbooks (e.g. [2]).

2 Methods

Indicators potentially useful in education were determined by a literary research.

Some indicators were then applied to data from a previous research performed by Iva Jakubská [3] for a rough idea of whether or not they could be truly used in practice. We chose a qualitative approach.

2.1 Basic concepts

Eye-trackers allow us to monitor and record eye movements using different methods, in our case the reflection of infrared radiation on the cornea.

Eye movements while reading a text can be divided into two groups – fixations and saccades [4]. Fixations are events lasting around 300 ms during which the eye is still, saccades are the movements connecting fixations. Regressions are a type of saccades that goes against the normal direction of reading. Areas of interest are parts of the tested material selected before collecting data as potentially important or interesting when evaluated separately.

3 Results

The literary research examined nine different sources. We created a table of thirty indicators sorted by which type of eye-tracking data they use, be it fixations, saccades, areas of interest or something else (e.g. Fig. 1). We added corresponding interpretations. Testing selected indicators on actual data showed some indicators were reasonably useful; others will require further testing. For example, qualitative analysis of recordings showed one participant knew what information was necessary for solving a problem, however they couldn't solve the problem successfully, indicating the problem was using the information. It also showed they paid attention to reading the problem, meaning they weren't just "being lazy" with their answer.

4 Conclusion

Providing a comprehensive list of eye-tracking indicators and their interpretations could give teachers valuable information about their students work and results. It could also be used for reference in further research in science education.

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Parallel 8 - Wroclaw/Guayaquil / 145

Experimental Activities from the Inquiry based Learning and from the reflections about of the Nature of Science

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Abstract. This work aims to discuss the importance of reflecting on the role of experimental activities in the teaching of Physics. Fundamentally, we discuss the use of experimental teaching activities from two dimensions: the first refers to the possibility of developing activities based on teaching by investigation, in which students are placed as agents in the construction of knowledge; the second dimension refers to the possibility of incorporating discussions about the nature of science in these activities. In this proposal we present two activities developed with basic education students, as well as some preliminary results.

1 Introduction
There are many works that point to the use of experimental didactic activities (EDA) as a fundamental teaching resource for the teaching of natural sciences, particularly Physics. In Brazil official documents, such as: the National Curriculum Parameters for high school (PCN) and the Curriculum Guidelines for High School (OCEM), emphasize the use of experiments as a strategy to address various themes as they are part of life, school and the everyone's daily life. These documents recommend that the experimental activities should not be carried out exclusively in a laboratory with scripts followed in the smallest details, but should start from a problem or question to be answered (BRASIL, 2002; BRASIL 2006). Galiazzi et al. (2001) present some of the justifications, pointed out by teachers, who highlight the importance of using experimental activities as a didactic resource: a) to stimulate accurate observation and careful data recording; b) promote scientific thinking methods; c) develop manipulative skills; d) train in problem solving; e) clarify the theory and promote its understanding; f) experiencing the process of finding facts through research, reaching its principles and g) motivating students.
Although there is some consensus regarding the importance of experimental teaching activities, we emphasize that such activities do not in themselves guarantee compliance with the aforementioned items. Contrary to a certain common sense, we point out that the EDA must be planned so that they achieve specific objectives.
2 Theoretical framework
The present proposal reinforces the importance of using experimental teaching activities as a fundamental resource for teaching natural sciences, in particular Physics, from the perspective of training critical thinking. Our approach is fundamentally based on two aspects: the first refers to the development of activities that place students as agents in the construction of knowledge. For this, we base ourselves on teaching by investigation as a theoretical framework; the second refers to the incorporation of reflections on the nature of science from the ADE. We point out the use of History, Philosophy and Sociology of Science in science teaching as a potential possibility for such incorporation (LEDERMAN, 2002; BRAGA et al., 2012).

3 Activity Proposals
We present two experimental teaching activities aimed at basic education students as practical elements of the proposed discussions.
The two activities presented in this work deal with themes related to electromagnetism. The first deals with the relationship between electric field and electric potential from field lines. In this activity, we discuss ontological issues – from the problematization of the concept of reality (materiality of field lines), as well as epistemological issues – from the discussion of the relationship between empiricism and rationalism in the construction of scientific knowledge. For this, we use a fragment of the text by Francis Bacon that composes the EDA . The second activity deals with the relationship between direct current (DC) and alternating current (AC), and approaches concepts of electromagnetism present in electrical voltage transformers and rectifier bridges. For the activity in question, we start from a historical episode that took place in the 19th century, which is presented through an edited video (based on the BBC documentary - The War of the Currents), from which we emphasize the social, economic, and subjective, present in the development and production of science and technology.

4 Some Results

The analysis of the data constructed from the dialogues between the students, as well as from the students' textual production, allowed us, in a preliminary phase, to build categories of arguments that raise dimensions that include elements that go beyond conceptual issues, favoring the construction of more complex representations of science.

Acknowledgements

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Parallel 2 - Wroclaw/Guayaquil / 146

CERN and Perimeter Institute Professional Development Programmes Impacts on Brazilian High School Physics Teachers

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CERN and Perimeter Institute are two notable institutions for their international teacher programmes in Switzerland and Canada, respectively. CERN has started its HST (High School Teachers at CERN) programme in 1998. Even though the first edition of this programme only had European teachers, it became transcontinental the following year. From 2006 on, CERN has expanded its programmes to different countries, each of them on its national language, while HST remained as an international teacher programme administrated in English.
The Portuguese Teacher Programme was inaugurated on 2007 and was soon expanded to a Portuguese Language Teacher Programme from 2009 on, when Brazil and Mozambique were invited to join (and later joined by other Portuguese-speaking countries), becoming one of CERN's first international teacher programmes in a different language than English. Through this programme, 244 Brazilian teachers had the opportunity to visit CERN from 2009 to 2019, not to mention those who were selected to attend HST or CERN's newer international programme: International Teacher Weeks (ITW).
Through a different perspective, Perimeter Institute also created on the early 2000's an international programme for teachers around the world called Einsteinplus. While CERN's programmes were mostly designed around lectures and visits to CERN's installations, Perimeter Institute's programme was designed around teacher resources to incorporate Modern Physics on the High-School curriculum. Although the resources were originally written in English, Perimeter Institute established a partnership with International Centre for Theoretical Physics – South American Institute for Fundamental Research (ICTP-SAIFR), which is based in São Paulo – Brazil, on which the resources were translated to Portuguese.
ICTP-SAIFR also promoted weekend hands-on workshops for teachers in different Brazilian towns from 2018 to 2020. With the covid-19 pandemic, those hands-on workshops had to adapted to an online format in 2020 and 2021. Even though online activities have some limitations comparing to the hands-on format, this made it possible to reach farther locations on Brazil. In 2021, the resources

were also translated to Spanish, so ICTP-SAIFR could reach not only Brazil and other Portuguese-speaking countries around the world, but also the Spanish-speaking countries, which comprehend most of Latin America.
This research was designated to evaluate the impact of CERN and Perimeter Institute's programmes on Brazilian teachers. The theoretical framework used to evaluate this impact was Thomas Guskey's Evaluating Professional Development [1], in which the impact is measured around five different levels: participants' reactions, participants' learning, organization support and change, participants' use of new knowledge and skills and student learning outcomes.
In order to evaluate all these five levels, a group of 30 Brazilians teachers from different parts of the country was selected and those teachers were submitted to a semi-structured interview, in which they could be asked some questions about their academical background and their work. Also, five schools in which some of these 30 worked (each in one of Brazil's five main geographical regions) were selected to investigate in a deeper way the teachers worked. So, some of the students and co-ordinators were also interviewed.
The results of this research showed mainly four distinct types of teachers with different demands. Those from state public schools represent the teachers with higher demands, since those schools are normally located on farther areas and with a poorer structure, while the teachers from private international schools face a totally different reality. Federal public schools have an intermediate situation and some of the teachers work on more than one school, so they had to be put on a separate group.

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Terrestrial and Extra-terrestrial Radioactivity

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Starting from a successful scientific dissemination activity, the idea was born of building a path towards radioactive phenomena that would integrate basic high school knowledge with aspects that characterize physics and attractive and motivating topics such as health and space. The route was presented in a reduced form at a *World Space Week* event. Given the interest shown by teachers and students, a more extensive version will be proposed among the didactic activities that the *Physics Instruments Collection* permanently proposes to schools as scientific education paths for active and aware citizenship.

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Astronomy Teaching - A didactic proposal for measuring the Equinox in Latin America

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Abstract. The purpose of this work was to create an experimental sequence that would allow Basic Education students (Elementary and High School in Brazil) to make daily measurements of the

Spring Equinox in the Southern Hemisphere, involving three Latin American countries, Argentina, Brazil, and Costa Rica. From a spreadsheet created in Excel software, by professors Josué Dionofrio and Diego Galperin [1], respectively professors at the ORT Technical School in Buenos Aires and the National University of Rio Negro, Bariloche, Argentina, students could learn about and determine the trajectory developed by Sun during the day, calculating angles as a function of measurements of the height of the gnome and the width and angle of the shadow cast by the Sun.

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Who is that girl? She is the one who took the first photo of a Black Hole!

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Dear Organizers

We would like to submit our abstract, entitled "Who is that girl? She is the one who took the first photo of a Black Hole!" to be presented as an oral communication (Presenting in realtime with record – Guayaquil time zone) in the III WCPE.

With best regards.

The authors.

Parallel 8 - Wroclaw/Guayaquil / 150

Physics Education from a decolonial perspective: a case study with the Brazilian curriculum

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The educational process is characterized as a set of pedagogical actions developed for a particular social group and provided with intentionality. In this sense, every pedagogical action involves an intention, which transfers and reproduces cultural patterns that materialize in social values and traditions. In this context, the postmodern decolonial thinking discussed by Quijano (2019), Mignolo and Walsh (2018), and Abdi (2011) are inserted, as well as the epistemological aspects given by Santos (2020). Thus, with this paper, we seek to present a case study developed in Brazil about the colonial influences that manifest themselves in the science curriculum of the State of São Paulo, Brazil, taking Physics as the context for analysis. For that, we used as a method of analysis the Discourse Analysis given by the perspective of Pêcheux (2015) about the ideological construction of the discourse. As preliminary results, we identified that the absence of an original Brazilian structure for the construction of the analyzed curriculum corroborates the perspectives of a form of colonization characterized by us as at the primary level, that is, epistemic.

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The public discussion on scientific truth: the case of Esperantist-Epideictic discourse on Flat Earth

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There is a growing distrust in the institutions and science in the middle of ideological struggles. Some studies associate the spread of misinformation with the rise of 'echo chambers' powered by social media. We scrutinize how the public discourses about the Flat Earth have been shaped, considering not only the Flat Earthers (denialists) discursive production but also those in the name of science (affirmationists) that are attacking denialist groups and ideas. Findings show scientific truth is a part of conversations about the Flat Earth movement, and the Esperantist-Epideictic genre of discourse can be an analytical tool for researchers and educators.

Parallel 1 - Wroclaw / 152

Enhancing second-level physics students' energy literacy

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Abstract. With the aging of the existing school building stock there is a need for low-cost solutions that enable long-term resource efficiency in schools and reduced greenhouse gas emission (GHG). The Energizing Education to Reduce Greenhouse Gas Emissions (ENERGE) project addresses this need using a range of targeted interventions that includes the design and implementation of pedagogical approaches that aim to enhance student's energy literacy. This study will outline the pedagogical approach adopted to enhance second level student's energy literacy, present activities that have designed and implemented in the physics classroom and share teacher's reflections on their student learning.

1. Introduction

With the aging of the existing school building stock (new schools/deep retro-fits can take years from planning to completion) there is a need for low-cost solutions that enable long-term resource efficiency in schools and reduced greenhouse gas emission (GHG). Effective energy education at school is important because it improves student engagement with carbon-reduction strategies. The Energizing Education to Reduce Greenhouse Gas Emissions (ENERGE) project addresses this need using a range of targeted interventions that includes the design and implementation of pedagogical approaches that aim to enhance student's energy literacy. At second-level, the concept of energy is taught as a cross-cutting concept in science and students build their knowledge about energy around four central ideas: energy transfer, transformations, dissipation and conservation (1,2). Energy literacy in education (3) expands on this understanding of energy and highlights the importance of systems thinking (the environmental, social, cultural, political, technological and economical dimensions of energy education) which allows learners to become competent at deciphering information about energy, making informed decisions, solving problems and taking action. In 2008, DeWaters & Powers have developed a widely employed set of criteria for measuring energy literacy in the classroom that is comprised of five key characteristics that describe energy literacy outcomes in three domains: cognition, affect and behaviour (4).

1. Methodology

The process used to design and develop the ENERGE pedagogical approach was carried out over several stages. The first stage involved a review of the national education models to identify opportunities for energy education within the national curricula across six partner countries in Northwest Europe (NWE), i.e., France, Germany, Ireland, Luxembourg, Northern Ireland and the Netherlands. The second stage involved a systematic review of literature to identify what types of knowledge, skills, attitudes, values, beliefs, and behaviours were associated with developing energy literacy. Based on the findings from research, policy and practice, the project adopted a pedagogical approach that is comprised of six characteristics as presented by DeWaters & Powers (4) (see Table 1). This pedagogical approach was used to design a collection of 46 energy teaching and learning activities (ENERGE activities) that could be adopted for use in the existing curricula in the six countries. The authors engaged in a process of co-design with second-level teachers (including physics teachers) working in ENERGE project schools in these six countries to develop and trial these activities in the classroom.
Table 2 presents seven ENERGE activities that have been piloted by teachers in ENERGE project schools in France, Germany, Luxembourg, Ireland, Northern Ireland and the Netherlands.

Table 1. Energy literacy characteristics (4)
An energy literate student:
- has a grounded understanding of science and how energy is harnessed and used to power human activity (C1)
- understands the impact that energy production and consumption have on all spheres of our environment and society (C2)
- is sensitive to the need for energy conservation and the need to develop alternatives to fossil fuel-based energy resources (C3)
- IS cognisant of the impact of personal energy-related decisions and actions on the global community (C4)
- strives to make choices and decisions that reflect these attitudes with respect to energy resource development and energy consumption (C5)

These activities are included in topics on the second level physics curriculum and are suitable for lower and upper second-level students. The selected activities explore student's personal use of energy in and examine their home environments to explore and debate issues surrounding energy use, energy conservation and energy efficiency in the home.

Table 2. ENERGE Activities mapped to Energy literacy characteristics presented in Table 1

Title of Activity	Related to Characteristic
Leaking Electricity "Phantom Loading"	C1, C3, C4, C5
Calculating the cost of energy in the home	C1, C2, C3, C4, C6
Calculating the cost of energy in the community	C1, C2, C3, C4, C6
Energy Sankeys: Calculating energy efficiency	C1, C3, C4, C5
My thermal comfort at home	C1, C3, C4, C5
Monitoring energy consmption in the home	C1, C2, C3, C4, C6
Calculating the payback costs of a low energy home	C1, C3, C4, C6

4. Conclusion
The pedagogical approach presented to address energy literacy has been successfully adopted in a small number of NWE schools. Widespread implementation of this approach will require strong curricular alignment and teacher collaboration to implement a transdisciplinary approach to energy education that will (1) enhance the development of students' energy literacy, (2) maintain student engagement in carbon-reduction strategies at home/school and (3) support teacher professional learning.
Acknowledgements
Energizing Education to Reduce Greenhouse Gas Emissions (ENERGE) project has received funding ftom Interreg NWE.

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Parallel 8 - Wroclaw/Guayaquil / 153

The articulation between the STS Approach and Environmental Education for the contextualization of Acoustics in Physics Teaching

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Environmental degradation is an increasingly present concern throughout society, and it is a reality that needs to be changed and surpassed. This implies an urgency shift in Basic Education in order to educate critical citizens whom will seek to maintain the best social-environmental conditions for human existence on their communities and on the planet as a whole. Noise pollution presents itself in an invisible, dangerous and permanent way, with effects which have a prolonged effect. High sound pressure levels are closely related to multiple negative effects on public health and to risk factors for various diseases. In school environment, acoustic discomfort does not only affect human health, but also affect the quality of verbal communication and student performance, interfering with concentration, writing, speech development, learning and reading comprehension. An adequate acoustic environment contributes decisively to an improvement in the process of teaching and learning, and enhances the interpersonal relationships involved in the educational process. In this sense, it is important to introduce subjects of Acoustics such as environmental noise into the contents of Science and Physics transmitted to high school students as well. In order to place science and technology in concepts linked to the social and environmental context that surrounds the students, preparing them for a balanced and responsible life in society, we seek to combine the STS Approach with Environmental Education, intending to develop didactic sequences that combine the strongly interdisciplinary content of Acoustics with an environmental awareness that goes beyond a mere conservationist reductionism. The Brazilian Common National Base Curriculum (BNCC) emphasizes the importance in Science Teaching of discussing the role of scientific and technological knowledge in environmental issues, in order to minimize human impacts and improve living conditions at the local, regional and global levels. In addition to the mandatory curricular knowledge, STS Education assumes a scientific and technological education based on social construction, culturally and socially contextualized. It deals with science, technology and its teaching as a way to influence the daily lives of students, developing skills such as the ability to analyze problematic situations while seeking possible solutions in a grounded and responsible manner. In their future lives, students may face the need to make decisions related to environmental practices, such as respecting sound levels that are comfortable for living in society as urban noise is a matter of global scope. Cities were designed and built for cars, based on a limited and wrong understanding of Nature as a separate entity, in function of human needs, which led societies to isolated positions, disconnected from the environment that surrounded them. Moreover, those social contradictions caused by the disorderly development of large cities are directly related to the aggravation of environmental problems and the failure to promote social welfare. In order to understand and transform the current reality, it is required the comprehension of science, technology, society and environment within a full context, as these dimensions are intrinsically complementary. Thus, the articulation between the fields of the STS Movement and Environmental Education can be an important strategy to overcome the supposed contradiction in the discourses on environmental conservation and scientific-technological development, especially those that undermine human formation in its entirety and that are linked to mere utilitarian projects.

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Our Unfriend, the Atom: the Case of a Stratospheric Nuclear Explosion North-American Test in the Northeast Skies of Brazil

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Abstract. The aim of this paper is to present an unknow fact occured in Brazil in 1957: three explosions of nuclear bombs realized in an diplomatic illegal way above the skies of the Northeast of Brazil. The explosions are a test to detect the possibility to create an electromagnetic barrier to avoid the exchange of radio comunications by the soviet government in a case of a total nuclear war. This terrible fact are not studied in the History and Physics textbooks in Brazil but it was documented by brazilian and north-american newspapers and by the references of Basbaum and Cornwall.
1 Stratospheric Nuclear Explosion in the Brazilian Northeast
Basbaum (1960) wrote:
The failure to re-establish diplomatic and trade relations with the countries of Eastern Europe and China, which are of such great interest to our economy, is an imposition of the United States in our foreign policy. And the famous Brazil-US military agreement, through which a US domestic law regulates relations between the two countries, is without a doubt a clear intervention in our domestic policy. Just recently, the United States exploded an A-bomb in the skies of the [Brazilian] Northeast without the governors and political leaders of our country manifesting in any wa. [1, p. 21]
It is very konwn that, during the Cold War, United States developed nuclear bombs to make test in the earthly stratosphere. The aim was to analyze the possibility to avoid radio communications or electronic guidance of nuclear missiles launcheda by soviets in a Nuclear War. The effect was terrible.
Cornwall wrote the memories of witnesses who witnessed the nuclear events in the year 1957:
It was around 7:00 pm (…) someone called their attention to a rising light… a large pink or reddish light spreading from the low mountain range that you see from the door towards Cacimba Nova. It was like a fern plant, streaking like coconut leaves.
The flash lasted so long that the animals left the surrounded place thinking it was a new day.
Ana (…) heard her mother comment that she saw the great light in the sky and that the day after there was dust above the plants. [2, p. 10-11]
It was evident that north-american realized an illegal nuclear test in a geographic area not allowed to conceed this madness. The New York Times related this event in its edition of 1959 [3] (Fig. 1).

Fig. 1. Edition of April 4th, 1959 – New York Times relating the nuclear experiment named Argus.
2 The Ou Unfriend, the Atom
Recently it was published a paper [4] when we analyzed the Disney's film, made in 1957, entitled Our Friend the Atom. This well-known film was a peice of propaganda of the north-american government to popularize the peaceful use of the atomic energy. But this is only the surface. The real aim of this film is to make a brain wash in large scale to the US citizens accept the use, also, in a new Great War. The idea, developing to the new brazilian curricula to High Schools is to work of contemporary physics in a historical and critical perspective, using for example, the conflicts between science and politics, for example. There is an obvious ambivalence between what is "friend" and what is "unfriend" in the field of ATOM.
3 Conclusion
The remarkable conclusion of this work is to introduce the theme of NUCLEAR PHYSICS but based upon real and unknow facts of the history of our science and humanity.

Acknowledgements

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Usage of Augmented Reality in Physics Education: Erasmus+ KA201 Project ARphymedes

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School physics is often mentioned as one of the least preferred subjects because the concepts can be complex and difficult to understand. At the same time, experiments are an important aspect to illustrate the process/concept/phenomenon, but there is often not enough time to do so. An interactive way that could increase students' motivation during these times and allow them to deepen their knowledge of physics is through the use of augmented reality. The aim of this paper is to present the project AR Physics made for students (acronym: ARphymedes), which addresses the above problem.

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TEP, PHYSICAL and tolerant exchange in higher education

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One of the great challenges that teachers have is to make the class interesting to students, since they are attached to the use of technology from a very young age. The student is surrounded by stimuli, it is not uncommon for them to go to school in many cases with their tablet and cell phone, which leads them to keep in constant communication with their classmates through messages or chats, it is very It is common to find them watching educational videos in the breaks of everything they consider interesting, and then upload them to a social network

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Integration between Mathematics and Physics in engineering students.

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The current work is the consequence of an action of a strategic nature that seeks to make the contribution of mathematics to the teaching-learning process of Physics more viable and in this way help the pleasant integration of students to the new entrance to university academic life . The Physics subject, taught in the second semester of the Engineering career, historically has problems in poor performance, which compromises the passage of students to other subjects and they need a solid knowledge, to be able to advance successfully. Detecting various problems, mathematical equations and trigonometry.

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Design principles about using simulators to improve student engagement in the physics teaching

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Incorporating new digital technologies into teaching is of fundamental importance in an interconnected world. In this sense, this work seeks to develop design principles on how to use simulators and recorded reports to improve student engagement and, consequently, learning. For this, we made a Design-Based Research (DBR) to identify the supports promoted using simulators. The main findings are that simulators accelerate learning through discussions in investigative practices and promote a type of engagement where students seek to learn beyond traditional exams.

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Spacetime globe: a teaching proposal for the didactics of Special Relativity

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Special Relativity introduces students to Modern Physics, whose importance in the Italian High Schools is increasing. Nevertheless to face the difficulties both teachers and students encounter different solutions have been developed.
We present an experimentation regarding the teaching of Special Relativity we performed in last year classes of High Schools, namely those specializing in scientific studies. In this project a mechanical instrument was used which allows to explain and show Lorentz's transformations, exploring by hands the effects of a change of reference frame. Teachers and students were able to deal "by eye" with relativistic phenomena.

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Mathematics in Physics Education: Enhancing mathematization in physics education by digital tools

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The GTG Mathematics in Physics Education follows the philosophy of supporting physics understanding by the conscious use of mathematical structures. The Symposium discusses the possible roles of digital tools in promoting physics understanding by fostering sensemaking of computations, geometrical visualizations or diagrams in a physics context.

Parallel 10 - Wroclaw / 162

Electrical Transport Measurements from First Principles: a Senior Undergraduate Experiment

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A final year undergraduate experiment has been designed and constructed with the aim of illustrating numerous aspects of low temperature measurements, with the objective of determining the electrical transport properties of materials. The experiment is designed to ensure that the students cannot treat the experimental apparatus as a data-producing "black box", and the students are obliged to manually control the temperature, take much of the data by hand, and to calibrate the thermocouple used to measure the temperature. The use of a desktop computer and software packages during the experiment are encouraged. Much of the apparatus was assembled at relatively low cost.

Parallel 1 - Wroclaw / 163

Pre-service physics teachers learn to give feedback to peers' physics laboratory reports

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Abstract. The aim of the study was to investigate the experiences of pre-service physics teachers who were introduced to and learned how to give feedback to peers' physics laboratory reports for improvement. Data sources included feedback given by the participants, weekly reflective journals and semi-structured interviews. 36 students participated in the study (in four cohorts) for one academic semester. It was found that the majority of students reported that peer-assessment and the exchange of oral and written feedback resulted in a better understanding and learning of assessment criteria related to the writing of laboratory reports.

1. Introduction

Research on classroom assessment provided evidence that peer assessment and good quality feedback can promote learning and encourage progress in student learning at secondary [1] and undergraduate level [2] as well as in teacher education [3,4]. In physics education research, there are studies which invistigated the development of instruments to assess laboratory reports with secondary and university science students.
The presented research study was carried out within a 13-week laboratory course designed for pre-service physics teacher education. The aim was to explore the experiences of pre-service physics teachers who were introduced to and learned how to give grades and feedback (oral and written) to peers' physics lab reports. Four cohorts of pre-service physics teachers in third- or fourth-year participated; in total, thirty-six (36) undergraduate students.
The main research question was: "How did pre-service phyiscs teachers experience peer-assessment?" with three sub-questions:
1. What difficulties and challenges did pre-service physics teachers experience? (when giving feedback and grades to their peers' lab reports).
2. How did their experiences and concerns develop during one academic term?
3. What sort of feedback did they give?
The study employed data collection involving collection of written feedback, reflection journals and semi-structured interviews. The analysis has provided a progression of assessment criteria and a typology of written feedback ranging from simple comments to comments related to the assessment criteria.
2. Findings
The process of giving feedback in the form of written comments resulted in participants taking more responsibility for their own learning. However, they seemed to give feedback as some advice not only for improvement and better quality of the lab report but also for a higher grade.
At the beginning of the course, the majority of students (86%) seemed to believe that grading is more difficult than giving oral and written feedback in the form of comments. In an interview situation, they explained this was the case because grades are important (in the specific educational context) and it was also difficult to give a grade to their peers. During peer-assessment experience and after some weeks, they emphasized that feedback is more important than grades because it helps them understand how they should improve the report and enhance learning. All of them experienced the transition from grading (as an important skill) to learn how to give feedback foused on improvement and informed by the developed assessment criteria. They talked explicitly about how they were supported by peers and how they helped each other identify strengths, weaknesses and missing points. It was also interesting to find out that the lower achievement pre-service teachers gave better feedback than the higher achievers. In the interviews, it was mostly them who emphasized that the process of peer-assessment helped them improve their laboratory report. Both the assessor and the assessee benefited from looking at their own work. Furthermore, they benefited from the process itself. The purpose was to internalize the quality, to develop and apply assessment criteria, to reflect

on them and give feedback while looking at peers' work. They would need to look again at the criteria when they received feedback from a peer. However, a few of them who submitted lab reports of high quality could not see any reason for peer assessment.
The findings are discussed in relation to those by previous studies [5,6] and in particular, to those [7] which showed that the greatest learning gains are secured for pupils initially classified as low attainers. A possible reason is that such pupils have previously suffered from lack of clear guidance and effective feedback. And finally, there is much room for improvement. Based on the findings, the main argument of the paper is about the role of pre-service teacher education for the development of classroom assessment skills and assessment knowledge in future physics teachers.

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Parallel 7 - Wroclaw / 164

Evolution of the 3rd Year Major Project at the University of the Witwatersrand

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The Major Project has been an important component of the 3rd Year Physics curriculum at the University of the Witwatersrand (WITS) for many decades. It has proven very popular with the students and has allowed academic staff to identify students with research potential as early as the final year undergraduate level. Student numbers have increased dramatically since 2015, and in 2018 the major project underwent a transformation, and since then students have completed an Independent Research Essay (IRE) under supervision of a member of the academic staff, with student teaching assistants providing support. The IRE may be used to inculcate or enhance essential skills for budding scientists, be they enrolled students or graduate student tutors.

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Tension between Preconceptions and the Canonical Physics Content: Teacher Interventions in a Dialogic Classroom

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Dialogic interaction in science classes provides students with opportunities to learn from their previous ideas towards the canon of science. This paper contributes to answering the question: How are the teacher's interventions in a dialogic class in order for the above process to take place? A comparative analysis of the interventions of a teacher in two introductory classes on electric circuits is presented. It is observed that the teacher's interventions play a key role in the progress of the students' models, but these interventions acquire different characteristics according to the context analyzed.

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Indirect Measures from Using a Remotely Controlled Experiment

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This study aimed to present and evaluate, in comparison with face-to-face experimental activities, the educational impact of a remotely controlled experimental activity. For this purpose, two experimental equipment was built for use with students and teachers of different classes of the1st year of high school in five public schools in the State of São Paulo. Before and after the experimental activities, a pre-test and a post-test were applied together to the students. The data showed that the experimental activity performed remotely contributed significantly to the students' learning when compared to the experimental activity performed in person.

Parallel 7 - Wroclaw / 167

A new Advanced Learning Platform for Analog Circuits and Automation for hybrid electronic practicals

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The COVID-19 lockdowns forced a hybrid form for our electronic lab course. To keep the necessary hands-on experience, we developed the Advanced Learning Platform for Analog Circuits and Automation (ALPACA). This ALPACA platform works either with Arduino or the Raspberry Pi Pico, the latter controlled within our desired language Python. The ALPACA was successfully used for at-home practicals; student evaluations were overall more positive than previous years. As student' motivation improved whilst the grades remained comparable, we continue the use of the ALPACA in the non-COVID era.

Parallel 10 - Wroclaw / 168

Supporting educational transitions in physics

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Transitions in education can provide several challenges for both students and teachers. Between the ages of 10 and 16 students undertake several transitions in their school lives. These include transitions across school systems (e.g. primary level to second level), transitions between different teachers, transitions across subjects (for example from a general science curriculum to a specialised physics curriculum). This symposium will discuss the approach and findings of the Supporting Transitions Across Mathematics and Physics Education (STAMPEd) project in supporting teacher professional learning and enhancing student learning outcomes across educational transitions in physics.

Parallel 8 - Wroclaw/Guayaquil / 169

Contribution of inquiry-based physics teaching and learning in initial teacher training

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Contribution of inquiry-based physics teaching and learning in initial teacher training

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Abstract. Inquiry-based science education is an educational strategy in which students follow methods and practices similar to those carried out by scientists to build new knowledge. The objective of this research is to analyze the challenges posed by inquiry activities in the initial training of physics teachers. The present study was exploratory in nature. The sample consisted of 49 students. The data were collected through the Mathematics and Science in Life questionnaire, MASCIL (Maaß, and Engeln, 2016). The results showed that this strategy is rarely implemented in physics classes; However, when this occurs, both students and teachers benefit.

1 Introduction
The self-evaluation processes and the review of the science literature have revealed that it is necessary to incorporate different strategies for teacher training. For this reason, dynamic methodologies that involve students and teachers in inquiry tasks in real contexts are lacking. It is essential that, in the face of the new challenges of humanity, physics education also makes changes with a view to achieving a better performance of pre-service teachers in initial training.
Inquiry Based Science Education (IBSE) is an educational approach wherein students follow methods and practices similar to those carried out by professional scientists to build knowledge (Keselman,

2003). The IBSE is a causal process that allows the student to formulate hypotheses and test them contrasting them through systematic experimental activities and / or observations (Pedaste, et al., 2012). This approach emphasizes the participation and responsibility of students to discover the knowledge that is new to them. With this approach, students often carry out a self-directed learning process, part inductive and part deductive, doing experiments to investigate the relationships of at least one set of dependent and independent variables. For its part, for several decades science education has insisted that it is necessary to modify, or at least renew, science teaching methodologies. Likewise, this methodology has been important for the development of scientific thinking (NRC, 2000).
Several quantitative studies support the effectiveness of IBSE as a major approach in science education. Alfieri et al. (2011), for instance, conducted a meta-analysis comparing inquiry with other forms of teaching, such as direct instruction or unaided discovery, and found that inquiry-based teaching resulted in better learning for students (mean effect size of d = 0.30). Likewise, in a recent meta-analysis carried out by Furtak, et al., (2012) which incorporated studies that used a wide range of terms to describe inquiry-based learning (e.g., subject learning and constructivist teaching) with an overall mean effect size of 0.50 reported in favor of the IBSL approach when compared with traditional teaching.
2 Research methodology
The present research was exploratory in nature and was based on the analysis of the information provided by a group of students from a physics teacher training program. Data were collected from 49 students and 15 professors. Both qualitative (coding) and quantitative (proportions; non-parametric statistics) techniques were used. Quantitative data were collected through the Mathematics and Science in Life questionnaire, MASCIL (Maaß, & Engeln, 2016). This Likert-type questionnaire consists of 77 items. The information was made available on an online platform and then administered under the supervision of two researchers. The participants were students of the Licensure Program in Physics from the Faculty of Education of Universidad de Antioquia, Colombia.
3 Results
The results showed that the belief that students benefit from IBSL is significantly related to the routine use of IBSL in physics classes (see Table 1). On the other hand, orientation towards IBSL is also correlated with the belief that students benefit from IBSL. Consequently, this effect allows a greater disposition towards the IBSL, in both students and teachers.
Description about the inquiry activities developed in physics class
Table 1 presents the descriptive and inferential results of the present investigation. Specifically, and for the case of descriptive analyses, the median and the absolute deviation from the median (MAD) were calculated. A comparison analysis of two independent samples was performed given the subscales of inquiry according to sex. The median and MAD values presented similar values for each of the subscales for the female gender (Me ± MAD = 2.87 ± 0.00), except for 'Application', 'Practical experiences', and 'Research', which had a MAD value = 1.00. In the case of the male gender, the median and MAD values presented similar values for each of the subscales (Me ± MAD = 2.75 ± 0.00). In 'Application', there was also a degree of variability. For 'Practical Experience', variables present differences related to the course taken. For the subscales 'Enjoyment', 'Inquiry Value', and 'Self-Concept', negative values were obtained (d = -0.064; d = -0.269; d = -0.121) respectively. This indicates that the female gender showed greater enjoyment in the inquiry activities than male gender.

Dimensions
(Subset of variables) Género p Value
U Mann -Whitney P Value Size effect (d)
Female gender. (N=16). Me±MAD Male gender. (N=33). Me±MAD
Enjoyment 2,87± 0,00 2,75±0,00 247.000 0.584 -0.064
Inquiry Value 2,87± 0,00 2,75±0,00 NaN -0,269
Self-concept 2,87± 0,00 2,75±0,00 NaN -0,121
Inquiry Interest 2,87± 0,00 2,75±0,00 286.000 0.586 0.083
Application 2,87± 1,00 2,75±0,00 295.000 0.493 0.117
Practical Experiences 2,87± 1,00 2,75±0,00 289.000 0.584 0.095
Research 2,87± 1,00 2,75±0,00 301.000 0.390 0.140
Table 1 Description about the inquiry activities developed in physics class
Conclusion
Promulgations of IBSL (Traditional Methods VS IBSE Methods). According to the results obtained, it can be considered that the facets of the IBSL have a relationship with the gender of graduate students in training, which can be supported by a marked correlation in categories such as 'Enjoyment' and 'Research'. On the other hand, an important facet is that of 'Self-concept', which needs more exploration. In the introduction it was mentioned that there are particular developments and expressions

of each student from the IB approach. These particularities seem to have negative or positive statistical variability according to the course and the orientations of the teachers who lead each course. In other words, the IBSL has not only cognitive, but also sociocognitive and psychosocial facets.

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Parallel 6 - Hanoi / 170

SITUATION OF STEM TEACHING AND LEARNING IN HIGH SCHOOL IN VIETNAM

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Unlike other developed countries in the world such as the US, Germany, Japan,… STEM education introduced to Vietnam is not derived from scientific and educational research or from macro policy on human resources but from robotics competitions for students from primary to high school levels implemented by technology companies in Vietnam together with foreign organizations. For example, the Robotics make X 2019 competition of STEAM Vietnam Hi-Tech Robot Joint Stock Company or some robocon competitions of companies such as Lego and some robocon competitions of other companies in the country. Since then, STEM education has started to spread in many different forms, many different ways of implementation, many different support organizations. Currently, high schools are also starting to introduce STEM into teaching, especially natural sciences such as Physics, Chemistry, Biology. However, the application is still spontaneous, sporadic in some schools, there is no synchronization due to the level of teachers, organizational funding, …
Keywords: Stem education, Current status and difficulties in STEM education

Parallel 8 - Wroclaw/Guayaquil / 171

Investigative Environmental Education: an Interdisciplinary Proposal

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Abstract. The environmental education is responsible for forming critical and actives individuals in their communities. The investigative teaching becomes an attractive alternative because the student is set off as the leading figure of the teaching-learning process generating a comprehension that the school contents are not disconnected from daily situations. To fulfil the proposed activities, experimental analyses will be performed with surface waters brought by the students from their communities objecting to verify the presence of hydric pollution. If any kind of pollutant is found, interdisciplinary and collaborative activities will be applied to find a solution to that problem.

1 Introduction

The preservation of aquatic environments, as all environments, has been the main subject of many debates in Brazil. To preserve aquatic systems are fundamental to maintain life as we know it. In that context, the spectroscopic techniques are among the most used for water quality analysis. On that, Arduino gains momentum, since it makes possible to create high efficiency equipment with low cost and their programming and handling procedures are quite simple.

In teaching, environmental education needs to be acknowledged due to its importance in making citizens participative in everyday environmental issues [1]. This proposal aims to cultivate abilities and competencies to analyse and solve relevant questions through a problem situation and a development of an intervention scheme.

In this project three specific methodologies are proposed: Reversed classroom; Investigative methodology; Transdisciplinarity [2]. With the assistance of other teachers, this proposal seeks to bring a plural knowledge around the theme through an approach of scientific aspects about water and its implications on modern society.

The main objective of this proposal is to create an educational ambience for the students to develop monitoring skills and decision-making abilities to solve environmental problems. According to Brazilian government guidelines it is supposed to discuss, at the classroom, the importance of preserving and conserving biodiversity, evaluating the effects of human interference and environmental policies to guarantee the sustainability of the planet [3].

2 Methods

The Arduino prototype will be the starting point to the interdisciplinary activities with Physics, Chemistry, Biology and Geography throughout the school year. The physics teacher will construct the Arduino photometer. At Chemistry, the questions surrounding coloured compounds water pollution will explicate. The geography teacher will expose the geopolitical and economic problems brought by water pollution. At Biology, the importance of hydric resources for physiological, fauna and flora issues within the context of population growth will be enlighten.

The photometer was calibrated using substances with well stablished colour levels in the literature, being copper sulphate and potassium dichromate. After calibration, the process of construction of a standard curve with the platinum-cobalt colour standard to analyse random surface water samples. The students are supposed to collect effluent water samples from their communities and, escorted by the results and with teacher's assistance, they shall develop, in groups, intervention schemes to be applied at the location they identify pollution.

3 Results and Discussion

The prototype presented satisfying results on the tests and random water samples analyses. To compare the photometer results, the analyses were also done by a spectrophotometer from DIDALAB brand, POF 010-361 model. The comparison was above the expectations, since the quality and precision of the photometer's analyses were superior to DIDALAB's spectrophotometer analyses. It was revealed that some locations on Petrópolis, in the state of Rio de Janeiro, there is dumps of coloured substances that modify the natural colour of water rivers, conferring a colour level above the limit stablished by Brazilian government.

4 Conclusion

This application shows the potential of the proposed activity, because the experimental method gives the student the possibility to develop skills, abilities and competencies, related to the identification of pollutants on their communities through the collected sample waters analysis and the group activities aid to growth social skills. By that, beyond learning, the student appears with useful tools to effectively make moves in their community environmental issues. The teaching project was not implemented yet, because the suspension of in-person activities in Brazil since March 2020 due to the pandemics.

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Parallel 7 - Wroclaw / 173

SVELAMI-B project results within primary schools

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The SVELAMI-B project aimed at carrying out STEM activities to elementary school children and secondary school boys and girls. We will present the project and its activities within two primary schools, outlining some results.

Parallel 3 - Hanoi / 174

STEMization of Physics teaching: Effectiveness and challenges

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Symposium
STEMization of Physics teaching: Effectiveness and challenges
Organizer: Nguyen Van BIEN
Abstract: STEM education has been implemented popularly since about 2005. STEM education fosters individuals in learning achievements, authentic problem-solving skills, interests in STEM subsubjects, and pursuing STEM careers. Nowadays, many countries have deployed STEM education, including Asian countries, to achieve STEM values for students. With the development of STEM education, an ongoing challenge to pre-service science teachers (PST) is developing STEM teaching

practice. Therefore, it is a significant concern to develop appropriate strategies for PST training programs in STEM education. We designed and implemented internationally the method course that strengthens modeling-based inquiry and integration of STEM education in Vietnam and Indonesia. The key features of the MII-STEM approach consist of real-world problems, constructing a STEM model, predicting, collecting data, testing solutions, and formulating hypothesis-proposal solutions. The results showed that PSTs positively changed perceptions of models and modelings. Besides, Indonesian PSTs had microteaching at acceptable levels.
However, successful STEM education required national conditions. One solution could be the implimention of specific subjects with the key features of STEM education, for example, innovative Physics teaching with STEM integration. In the following parts, we presented empirical studies of implementing STEM education in Vietnamese classes. Such empirical studies affirmed the successful implementation of STEM education in Vietnam.

Speakers:
Nguyen Thi To Khuyen: Impacts of method courses on Vietnamese pre-service teachers' perceptions and practices: From the perspectives of model and modeling in STEM education
R. Ahmad Zaky El Islami: MII-STEM Implementation in Indonesia: A Pilot Study
Nguyen Anh Thuan: Building STEM teaching materials for the topic "Energy and life" to develop scientific competencies of junior high school students
Tuong Duy Hai: The role of Coach 7 software in STEM education for a primary and secondary school in Vietnam

Parallel 7 - Wroclaw / 175

Eating in Space: From Spatial Delicacies to Star Farms

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Eating is a primary problem in space exploration. Space and terrestrial research in physics, chemistry, biology, and physiology highlight several interrelated and fundamental aspects in solving this problem. Although many educational activities, especially in chemistry and biology, are available on the websites of the space agencies, a more structured interdisciplinary introduction is necessary to spread this way of approaching scientific issues through current themes in contemporary society.

Parallel 7 - Wroclaw / 176

Learning difficulties in the interpretation of Feynman diagrams

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Feynman diagrams are an essential part of theoretical elementary particle physics but they are also used in popular science publications as well as in scholar teaching. In an exploratory research study, questionnaires were presented to teachers and university students in which simple Feynman diagrams were to be interpreted and judged concerning their usability at school. In particular, topologically equivalent diagrams with different line geometry and different visualizations of the time direction were used. In the responses, general as well as visualization-specific potential learning difficulties and misconceptions were identified and categorized.

Parallel 7 - Wroclaw / 177

Computation in physics education: a toy model for viscosity

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Abstract. A computational toy model for viscosity in gases is presented. The model, appropriate for undergraduate university and (in part) for high school students, is based on an iterative representation of the exchange of matter between a succession of trains sliding on parallel rails, representing the reciprocally sliding layers of a fluid in laminar motion, that is the usual mesoscopic model for defing viscosity. The model is useful both to improve students cohomprension of viscosity and to consolidate their computational skills, giving in the meantime pedagogically useful hints on the physical interpretation of the elements of a matrix: a useful skill in view of the students' learning of quantum mechanics.

1 Introduction
Computation has become so important in physics education [1] that it justifies such claims as "…a curriculum in which computation is absent or plays a minor role is inauthentic to the contemporary discipline" [2]. STEM disciplines (and their teaching/learning processes) traditionally relie on two pillars: theory and experiment. This state of affairs has profoundly changed in recent decades, when a real paradigm shift has occurred, ignited and promoted by the wide availability of computers and the increasing power of computational tools, even of educational grade [3]. The theory/experiment duo has been significantly changed by the development of a real third pillar, i.e. computation, that "… has blurred the distinction between theory and experiment" [3]. In this context, a major role of computation and programming is highly appropriate in the preparation of high school and university undergraduate students [4] and, even earlier, in primary education [5].
Viscosity is a property of fluids often affected by misconceptions [6]. In particular, the concept of viscosity as "friction in fluids" (as it is defined in many tesxtbooks), by evoking the intermolecular interactions giving rise to friction between solids, could be didactically misleading, since students are led to overlook of viscosity as a transport phenomenon [7]. On the other side, properly modelling viscosity as a transport phenomenon is not feasable at high school level, nor for university undergraduates, since it would require employing the Boltzmann transport equation [7].
In this context, we present a new computational toy model for viscosity, which is articulated in steps of progressive difficulty and completeness, and allows students to computationally explore the shearing behaviour of a gas when some parameters are varied. The proposed toy model is equipped by multimedia features, by implementing a (partial, for now) graphical user interface, based on the interactivitiy capabilities of the software Wolfram Mathematica.

2 The toy model for viscosity
The model is based on the mechanical coupling between many systems, by the exchange of matter. In particular, it relies on the analogy between: on the one hand, the usual model of a fluid flow in terms of layers sliding over each other; on the other hand, a succession of bodies (trains) free to slide on a series of parallel tracks. Sliding trains exchange massive balls each other, resulting in a net trasfer of momentum from faster trains to slower ones (Fig. 1).

Fig. 1 The layered model of a flowing fluid is transposed in the analogical model: N trains sliding frictionless on N parallel rails. Each train exchanges massive balls with its two nearest neighbors. This exchange causes the momentum to flow transversally with respect to the direction of motion of the trains.

The time evolution of the system (when the first train is acted upon by a constant force parallel to the rails, while the last train is braked by a conventional friction force) is obtained by an iterative process. Each step of the iteration is formulated as an appropriate matrix operation, so that the overall time evolution can be expressed as powers and sum of a single matrix, whose elements are readily interpreted in terms of interaction between a given train and its neighbors. The computational implementation of the model by means of the Wolfram Mathematica software allows to interactively explore many aspects of a typical viscous flow, such as the concept of velocity profile through the flux and the role of various physical parameters, whose physical meaning can be highlighted by comparison with the parameters of the computational model.

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Parallel 2 - Wroclaw/Guayaquil / 178

Physics problems directed to biology: a contribution to the initial teacher education through the complexity in problems proposed by Halliday volume II

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This study presents a qualitative research whose central theme addresses the theory of solving complex physics problems, based on the complexity of Edgar Morin and the definition of poorly structured problems by David Jonassen, linked to the initial training process of the biological sciences teacher. The research was developed in the context of the discipline of Interdisciplinary Projects V, which is part of the syllabus of the undergraduate course in Biology and has a proposal for scientific and technological literacy for students.
The course was chosen after a detailed analysis of the four volumes of the textbook used in undergraduate Physics, entitled "Fundamentals of Physics" by the authors Halliday, Resnick and Walker. After the analysis, it was found that there were several complex problems that could be explored during the undergraduate course in Biology, allowing future professors a broader view, not only of physics, but also of several other concepts. Volume II contains a wider range of complex issues in Physics linked to Biology, questions about gravitation, waves and thermodynamics.
Therefore, this book was chosen to extract and analyze complex problems. In this context, we understand that complexity "is what is woven together" (MORIN, 2013, p. 258), therefore, the complex relationships that exist within a problem must be taken into account in order to foster knowledge and debate within the science. According to Jonassen (2000, p. 84) "the few problems that students encounter are usually well-structured (history) problems that are inconsistent with the nature of the problems they need to learn to solve in their everyday lives". Based on this premise, we arrived at the application of this study, whose emerging problem was: What learning relationships can be built with undergraduate Biology students based on the discussion of complex fluid problems in Halliday? To solve this problem, we used the Grounded Theory (data-based theory) as a methodological strategy, which seeks to idealize theories going inversely to what positivist methodologies bring.
This methodological resource allows the researcher, when going through the three stages of codification (open, axial and selective), build a new theory with the collected data. Based on this relationship, we built a didactic sequence, in order to familiarize students with the complexity and solving of complex problems. Discussions and analyzes of all stages of classes revealed that students did not have

complex thinking and did not know this approach, but when instigated they changed their worldview, making it possible to open and establish a dialogue between scientific knowledge, situations daily life and the interrelationships within science and within distinct areas. On a new approach to solving complex problems, we found that three codes were essential for their visualization to be modified during the stages, namely "research, historical valuation and teacher training" (CORREA, 2020, p. 2-65) . Through these data, teachers from the most diverse areas, based on the theory of complex problems, can use the three indicators for a new conceptualization of the problems to be applied.

Parallel 8 - Wroclaw/Guayaquil / 179

The use of "The Diary of the Sky" as a teaching strategy for Astronomy in the context of the continuing education of Basic Education teachers

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Abstract. This text describes one of the phases of a broader research, carried out by the Grupo de Pesquisa em Ensino de Ciências, UNESP, Bauru Campus, São Paulo (SP), Brazil, which has shown the gap between the academic production in the Astronomy Tuition field and the knowledge and practices of graduates and teachers employed in Basic Education. Seeking to intervene in this scenery, this study takes into account some of the expectations, limitations and difficulties pointed out by a group of Basic Education teachers, from the public school system in Bauru, based on the use of the 'Diary of the Sky' as a teaching strategy in Astronomy.

1 The educational formation in Astronomy Education

Although the growing presence of initiatives aimed at Astronomy teaching in Brazil and abroad, according to results of research carried out in the Astronomy Tuition field, among which [1], [2], and [3] stand out, respectively, presents promising data regarding the professional formation in Elementary, Middle and High levels of Basic Education, as well as in the official curriculum programs of Further Education Institutions, with emphasis on the development of teaching, extension and divulgation projects, for example, it also equally reveals the need of giving meaning to astronomical disciplinary knowledge, in different educational contexts, within a longitudinal development that is coherent in itself and with the student's everyday experience.

In this sense, from an extensive research in Astronomy didactics, of cooperative character between Brazil and Italy, developed between Grupo de Pesquisa em Ensino de Ciências (GPEC), of the Faculdade de Ciências, UNESP, Bauru Campus (SP) and Gruppo de Ricerca sulla Pedagogia del Cielo, of the Movimento di Cooperazione Educativa‖ (MCE), Rome, Italy [4], this study takes into account, in a brief report, some of the expectations, limitations and difficulties pointed out by a group of Basic Education teachers, from the public school system in the city of Bauru, São Paulo, participating in a continuing education course entitled: Diary of The Sky - Introduction to Astronomy Didactics for Basic Education Teachers.

The qualitative methodology in use, based on the proposed objective, made it possible, with the group of teachers and their students, to obtain data from the use of the didactic-pedagogical material Il Diario del Cielo, in the format of an astronomical school diary [5], originally elaborated for the reality of the Northern Hemisphere, by Prof. Dr. Nicoletta Lanciano, from the Università "La Sapienza" di Roma and coordinator of the MCE, being then translated and adapted to the reality of the tropical strip of the Southern Hemisphere [6].

The teaching and learning activities developed throughout the course, starting from the sequence of activities proposed in the book Diary of the Sky, consisted in the presentation of the conceptual framework related to everyday astronomical phenomena, with emphasis on the recognition of the local horizon, spatial-temporal orientation, times of rising, culmination and setting of both Sun and

Moon, duration of the day according to the period of the year and latitude of the place of observation, seasons of the year, phases of the Moon, among others, and in the deepening of educational aspects and cognitive peculiarities of Astronomy didactics, appropriating elements of Observational Astronomy, such as: a) active, direct and systematic observation of the sky and surroundings; b) activities with explanatory didactic models and c) outdoor work
2 Conclusion
Among the obtained data, after the completion of the work, there is evidence that teachers, in general, showed to be favorable to the proposal and use of the Diary of the Sky as a teaching strategy for Astronomy, favoring the mobilization of new understandings, product of individual and collective work, to observe the sky, to build the proposed instruments, to visualize and exchange materials, to discuss and evaluate the path, methods and learning processes involved.
Although teachers have signaled the need to overcome gaps present in Astronomy education and its tuition, the difficulty in managing school time and space during the process of implementing the Diary of the Sky with students and the lack of a habit for a direct and systematic observation of natural phenomena, they considered the proposal relevant in order to enable students to articulate concepts, models and theories with what is observed in real time daily in the sky, along with the distinction between evidence and interpretations of phenomena and experiences, the sharing of hypotheses, inferences and different points of view, in addition to the co-responsibility of the learners in the sense of making their own discoveries about the themes in matter.

Acknowledgements

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Parallel 3 - Hanoi / 182

How to develop modelling competence for Vietnamese students

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How to develop modelling competence for Vietnamese students
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Abstract.
Developing modeling competence is an educational objective in many countries such as "SEP 2: Developing and Using Models" in Next Generation Science Standards (NGSS). In Vietnam, the new physics-education curriculum has clearly defined the key learning outcomes, including modeling-competence elements as well. Experiencing modelling cycle is an effective way to develop modelling competence for students. Our recent work studies which tool is suitable for students and how to integrate this tool in modelling activities. This paper presents the use of Coach 7 modelling software to investigate common physics phenomenon of oscillations, shows feasibility and effectiveness of these activities via tryout.
1. Introduction
Development of modeling competence is an educational goal in many countries, for example "SEP 2: Developing and Using Models" in Next Generation Science Standards (NGSS). In Vietnam, the new physics-education curriculum has clearly defined the key learning outcomes which include modeling-competence elements such as understanding model/modelling, developing model, and using model in reasoning and predicting real-life phenomenon (Table 1).
Table 1. Framework of modeling competence, adapter from Papaevripidou, Nicolaou Constantinou (2014) and Mei-Hung Chiu, Jing-Wen Lin (2019)

Modeling cycle is a cognitive method used by scientists in many fields to describe, explain, and predict about systems, phenomena, complex process. Experiencing modelling cycle is an effective way to develop modelling competence in students.
2. Integration of Coach in modelling activities in schools
Authentic inquiry of physics phenomena must consider friction, energy loss, and change of influential factors. For example, the oscillation of spring pendulum can be damped by fluid resistance. Regarding theoretical deduction, this consideration often yields to differential equations which school students cannot solve with their current mathematics knowledge. Modeling by Coach 7 (Ellermeijer, Tran, 2019) helps to investigate both mechanical and electrical oscillations (Figure 1, Figure 2).
Based on the modelling cycle (Figure 3), the modelling method for teaching real-life phenomena with modelling tool like Coach is developed. This method is elaborated into modelling activities to investigate electrical oscillation in LC circuit and then tried out with 30 students in a gifted high school in Vietnam to evaluate if it can help to develop student's modeling competence.
Fig.3 Phases of modelling method for teaching real-life phenomena and opportunities to develop the corresponding elements of modeling competence

1. Tryouts and discussions The school tryout showed that students can fulfil phases of modelling method. Modelling performance indicators: "identify the nature of the phenomenon, the real life process", "evaluating and revising models" were observed in most students, while other indicators were not yet. There need more modelling activities with Coach to develop in students modelling competence to larger extent.

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Parallel 6 - Hanoi / 183

The Natural Science Teacher Training Program meeting the demands of the New General Education Curriculum in Vietnam

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The article gives a detailed introduction and a necessity of the Natural Science Teacher Training Program for lower secondary schools since 2018 in Vietnam meeting the demands of the New General Curriculum. We make a comparison between two programs in Vietnam versus that of Edith Cowan University, Australia in terms of comparing the program objectives and domains of knowledge in the training curriculum. We based on the documentary reviewing method and a comparative and descriptive approach about course descriptions to classify a common category for these programs and show typical and highlight points in each program that significantly contribute to the program development in Vietnam.

Parallel 6 - Hanoi / 184

AFFECTING INQUIRY-BASED LABORATORY ON THE DEVELOPMENT OF STUDENTS' EXPERIMENTAL COMPETENCY: A SYSTEMATIC LITERATURE REVIEW

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The purpose of this systematic literature review is to analyze the researches trends inquiry-based laboratory on the development of students' experimental competency. The PRISMA approach was used this systematic review by conducting the literature search using two online databases SCOPUS and ERIC. We found 48 studies published from the years 2011 to 2021. We classified these studies under eight themes: (1) the traditional and inquiry-based laboratory (IBL), (2) IBL implementation and curriculum, (3) types of IBL, (4) students' perceptions of teaching assisstants and benefit of IBL, (5) IBL to enhance skills and knowledge, (6) students' attitude towards IBL, (7) the factors support student learning in IBL, (8) IBL to improve students' autonomy and self-efficacy.

Parallel 6 - Hanoi / 185

STEM-education project Automatic light in response to ambient light for 11th graders to develop creativity and problem-solving competency

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In this article, we present a study on the design and organization of STEM-topic teaching on making an automatic light in response to ambient light to develop creativity and problem-solving competency – one of the General Education Program 2018's general competencies. We will provide students with a portion of the knowledge from Symposium 11.3 – "Introduction to electronics" in the Physics Program 2018 in this topic. The Engineering Design Process was used to create the lesson plan because it requires students to overcome obstacles while solving real-world problems. As students engage in learning activities, their creativity and problem-solving competencies grow.

Parallel 6 - Hanoi / 186

Determination of problem-solving competency framework associated with student's majors

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We have consulted with 20 experts in Theory and Physics teaching methods about the reliability and validity of the Elements of competency and Behavioral indicators in the built structure table. Collected data were coded, processed, and analyzed by excel. Based on the comments, the study has reviewed and adjusted the components and behavioral indicators accordingly.
After consulting experts from the adjusted structure table, we surveyed the students' confidence level for each behavioral indicator of problem-solving competency associated with students' majors. The sample in the study was a convenience sample, including 60 engineering students from Ba Ria - Vung Tau University who studied General Physics participated in the survey. The 5-level Likert scale tool is used for variables related to students' confidence when solving problems associated with their major. Collected data were entered and coded in excel, then processed by SPSS software. Analyze Cronbach's Alpha coefficient to check the reliability of the scale.
We will discuss the results more clearly when the articlce is presented in workshop

Parallel 5 - Wroclaw/Guayaquil / 187

The IPPOG Resource Database: Making particle physics outreach & education available worldwide

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The International Particle Physics Outreach Group (IPPOG) has been making concerted and systematic efforts to present and popularize particle physics across all audiences and age groups since almost 25 years. Today the scientific community has in IPPOG a strategic pillar in fostering long-term, sustainable support for fundamental research around the world. One of the main tools IPPOG has been offering to the scientific community, teachers and educators since almost 10 years is the Resource Database (RDB), an online platform containing the collection of high-quality engaging education and outreach materials in particle physics and related sciences. After almost 10 years, a new digital portfolio aiming to greatly broaden the audience type and strengthen the user experience, is being developed including a new RDB, which is currently undergoing a major curation process in order to ensure the resources are up-to-date and of the highest quality. IPPOG wants the new website to become more open to students, teachers, and the general public and the new RDB to become the primary source of particle physics outreach material in the world, which would help to bring particle physics closer to the society.

Parallel 8 - Wroclaw/Guayaquil / 188

The use of films in Brazilian Science teaching

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Abstract. The present work intends, through a bibliographical survey of Brazilian teaching journals, to analyze the use of films in Science teaching. From the analysis of several articles, it was possible to verify that the film in the classroom is rarely used in a critical way and is used more in an instrumental way.

Parallel 1 - Wroclaw / 189

"Active Learning" in the time of COVID?

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Active learning techniques have been employed in the final year Statistical Physics module since 2009. The introduction of these methods resulted in increased student participation during lectures, and improved student performance in assessments in comparison to the period 2005 – 2008. Student attitudes were probed using a number of surveys, and these were found to be overwhelmingly positive. An increase in student number from 2015 onwards coincided with a drop in student performance and participation in lectures. While active student participation was encouraged during on-line teaching over the last two years, student attendance and performance has been disappointing, particularly in 2021.

Plenary 2 - Hanoi / 194

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Lessons learned and unlearned: A lifelong journey with 'Active Learning' as a constant companion

Plenary 1 - Wroclaw/Guayaquil / 195

KEYNOTE SPEAKER: DR. YARON LEHAVI

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Crosscutting concepts in science education: Illusions, challenges and hopes

Plenary 3 - Hanoi/Wroclaw / 196

KEYNOTE SPEAKER: DR. PRATIBHA JOLLY

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Innovation, Enterprise and Physics Education: Weaving Paradigms for the World of Work

Plenary 4 - Wroclaw/Guayaquil / 197

KEYNOTE SPEAKER: DR. TOMASZ GRECZYŁO

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Video clips in physics education

Plenary 7 - Wroclaw/Guayaquil / 198

KEYNOTE SPEAKER: DR. PAULA HERON

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Improving student learning in physics: The dual roles of conceptual understanding and reasoning ability

Plenary 5 - Hanoi / 199

ALOP Workshop - Part 1

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Active Learning in Optics and Photonics (ALOP) is a teacher training program designed to strengthen the introductory physics learning environment, especially in developing countries. It was developed by UNESCO and is currently sponsored by SPIE and ICTP. ALOP updates teachers on introductory optics and photonics and introduces them to active learning strategies that have been demonstrated to be more effective than traditional instruction. A full 5-day, intensive, hands-on-minds-on ALOP workshop was originally scheduled in Hanoi, parallel to WCPE 3. Because of the pandemic, this three-hour virtual introduction to ALOP is being offered. During the two 1.5-hour sessions, participants will actively experience sample activities from each of the five ALOP modules. They will also receive an electronic version of the entire ALOP Training Manual and information on scheduling a live workshop once the pandemic is over.

Plenary 8 - Hanoi / 200

ALOP Workshop - Part 2

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Active Learning in Optics and Photonics (ALOP) is a teacher training program designed to strengthen the introductory physics learning environment, especially in developing countries. It was developed by UNESCO and is currently sponsored by SPIE and ICTP. ALOP updates teachers on introductory optics and photonics and introduces them to active learning strategies that have been demonstrated to be more effective than traditional instruction. A full 5-day, intensive, hands-on-minds-on ALOP workshop was originally scheduled in Hanoi, parallel to WCPE 3. Because of the pandemic, this three-hour virtual introduction to ALOP is being offered. During the two 1.5-hour sessions, participants will actively experience sample activities from each of the five ALOP modules. They will also receive an electronic version of the entire ALOP Training Manual and information on scheduling a live workshop once the pandemic is over.

Parallel 8 - Wroclaw/Guayaquil / 201

In-service Physics Teachers and use of Sensors in the Light of Principles and Tenets of Human Learning, introduction to sampling frequency

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Sensors specially designed for use in schools to measure values of physical quantities within science education have its firm place in the theory of science education for some decades already. However, there are many teachers and schools where sensors are not used. Some schools do not use any sensors, and others use sensors designed for industrial use. In this contribution, the effective use of sensors is discussed in the light of principles and tenets of human learning, as proposed by colleagues researching the application of neuroscience to education. The focus is put on in-service physics teachers training.

Parallel 2 - Wroclaw/Guayaquil / 202

Education and Formation: STEM in the Tradition of Alexander von Humboldt

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Parallel 2 - Wroclaw/Guayaquil / 203

Education and Formation: STEM in the Tradition of Alexander von Humboldt

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Differences and similarities in approaches to physics LAB-courses

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Insights and Reflections in Physics Teaching and Learning at High School and University

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Innovation in Kindergarten and Primary School Teacher Education in Physical Sciences

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Innovation in Kindergarten and Primary School Teacher Education in Physical Sciences.

Speakers
Federico CORNI
Faculty of Education, Free University of Bozen-Bolzano (Italy)
Stamatis Vokos
Department of Physics, California Polytechnic State University at San Luis Obispo, USA

Description

Symposium
Innovation in Kindergarten and Primary School Teacher Education in Physical Sciences.

Responsibles:
Federico CORNI
Faculty of Education, Free University of Bozen-Bolzano (Italy)
Stamatis Vokos
Department of Physics, California Polytechnic State University at San Luis Obispo, USA

Introduction
Innovation in Primary Teacher Education in Physics is crucial at a time of rapid development of science and technology in society and in response to the growing need for a modern scientific preparation of new generations to help them to cope with future challenges. The four contributions in this symposium come from four very different settings, giving fertile ideas that have matured in different contexts. They are united by their grounding in scientific education and primary teacher education research and develop our theme from two relevant points of view, i.e., integration and technology. Two contributions present integrated approaches to teacher education: the first integrates metacultural, experiential, planning and situated activities, while the second integrates nature, human and social disciplines. The remaining two contributions deal with the need to include engineering design and ITC technologies in school and in teacher preparation.
This symposium is sponsored by the GIREP Thematic Group "Physics Preparation of Teachers in Grades K-6" in view of its interest in knowing and discussing promising strategies to professionally prepare a new generation of kindergarten and primary school teachers.

Description of presenters:
Leslie ATKINS ELLIOTT, Boise State University, 1910 W University Dr, Boise ID 83725 (USA).
José CANTO', Experimental and Social Sciences Teaching Department, University of Valencia (Spain).
Marisa MICHELINI, Research Unit in Didactics of Physics, University of Udine (Italy).
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Discussant
Marco GILIBERTI
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Integrating Engineering into Physics for Future Teachers
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Abstract. In the United States, the Next Generation Science Standards calls for engineering — and particularly engineering design — to be part of students' science education throughout primary school, with engagement in engineering practices integrated into students' learning of disciplinary core ideas. We describe how opportunities for engineering emerge in the context of a course on scientific inquiry for future teachers, efforts to expand on those opportunities to better align with engineering design, and how these opportunities differ in important ways from more typical engineering design activities. In addition, we argue that engineering activities can support and sustain rich, meaningful inquiry.

1 Background
The Next Generation Science Standards (NGSS) [1] calls for engineering — and particularly engineering design — to be part of students' science education throughout K-12, with engagement in engineering practices integrated into students' learning of disciplinary core ideas. However, few prospective teachers have an engineering background, nor are they likely to receive even a cursory training in engineering while in their undergraduate degree program.
And while designed artifacts (labs, devices) are central to scientific activity — a critical component of how scientific ideas are constructed — curricular examples of engineering for science are rare. Instead, existing curricula that integrate science and engineering primarily treat engineering as an application of scientific theory or a way of engaging students and inspiring scientific questions (e.g., [2]). For programs that hope to prepare science teachers to integrate engineering design into the development of scientific content, in ways consistent with NGSS, there are few models to draw from.

2 About the course
The course described here [3] is taking steps to address this. Initially the course was developed prior to NGSS, when the "inquiry standards" stood alone; therefore we focused on students' constructing and vetting scientific explanations without explicit attention to the correctness of those models or a commitment to the particular content being addressed. While instructors selected a phenomenon to launch our inquiry, this flexibility with content allows the course to be more responsive to questions that emerged. Topics varied, and included light, color, sound, astronomy, energy and time. Materials in the classroom varied as well, and are generally inexpensive, "everyday" materials (flashlights, plastic clocks), or "raw ingredients" (lenses, mirrors, inks, tape, string). These were available in the room or in an adjacent stockroom. When class is not in session, experiments were stored, not disassembled.

With the introduction of NGSS and engineering into primary and secondary education, we noticed the role played by designed artifacts in our course. Students frequently modify materials available, bring in new materials from home, deconstruct and reconstructing physical artifacts to support their inquiry. We identify these as rich moments to engage in purposeful engineering design. Below we briefly describe two exemplar moments. Our presentation will focus on these moments, efforts to capitalize on these for engineering design, and how they support and sustain engineering and scientific inquiry.

2.1 Opportunities for engineering

The two brief vignettes below describe how emergent questions sponsored opportunities for engineering design, which then informed our continued inquiry.

1. Absorption of light. As students in one course modeled shadows, a question emerged regarding the absorption of light: after how many reflections was our light too dim to be seen? One student constructed a kinked construction paper tube with a flashlight at one end. By placing the kinks so that she could no longer see the flashlight bulb, she was able to determine that, after 4 reflections, light from the bulb was essentially all absorbed (for black paper; 6 for white).

2. Measuring speed. In a semester focused on energy, students were using a Gaussian Gun to model energy transfers and transformations [4]. A debate arose as to whether the magnet itself provided energy to the ball; to resolve this students needed to measure that speed – for a ball accelerating rapidly over a very short distance. Among the more creatively engineered methods was the 3-d printing of a surface on which the balls would roll so they could record the sound and, from this, determine speed.

3 Conclusion

This presentation describes how opportunities to engage in meaningful engineering emerge in scientific inquiry, and how we have capitalized on those moments to support engineering and sustain the inquiry as well.

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The virtual voice assistants in early science learning: an opportunity in Early Childhood Education

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Abstract. Technology is present in our lives and is also increasingly present in the classroom, as an educational tool. This fact must also have its transposition in the initial teacher training. This contribution presents a work in which virtual voice assistants are introduced as a tool in the teaching of science in early childhood education. We want to show the ideas from a group of 40 future teachers in their last year of the Degree, about the usefulness and the didactical possibilities of using virtual voice assistants as a tool in the teaching of science in early childhood education.

1 Introduction

In recent years, the common use of Information and Communications Technology (ICT), artificial intelligence and robots has spread across all educational stages including Early Childhood Education [1]. Consequently, children are exposed to digital devices from an early age. In addition, it has been proven that students work well in these digital contexts and even enjoy their use and the fact that they can speak directly to the machines [2] [3]. In this way it is not strange that in the educational field, we find that robots have been used as classroom assistants [4], or that they are even used as a tool to meet special needs in the classroom such as functional diversity or autism [5]. In this work we intend to reflect upon and investigate the usefulness of a particular multimedia resource that, for the time being, has not expanded into classrooms like those mentioned above: virtual voice assistants (VVAs).

Some works [6] [7] showed that VVA can have a greater impact on a child's cognitive development than when interacting with other devices such as computers or smartphones. In addition, they can also serve to modify many social dynamics both in the school environment and in the family environment. The key to the use of VVAs in Early Childhood Education for science is that the user interface is oral and is therefore accessible to children at this educational stage. To this, we must add that there have been significant improvements in current VVAs regarding the so-called error rate when specific questions are asked that allow a more fluid interaction with them. In this perspective, VVAs can be an effective tool to develop the potential of younger children while becoming a facilitator element for the teacher and allowing for autonomous learning. Other advantages of its use are its ease of installation (it only requires a power outlet and internet connection), its low economic cost, as well as the diversity of models available on the market (Amazon's Alexa, Apple's Siri, Google voice search…).

2 Methodology
Through focus group work, 40 students in the last year of the Infant Education Teacher degree at the University of Valencia (Spain) have reflected on the possibilities of using virtual voice assistants as a tool for teaching science in early childhood education. They have to address some questions, such as: What are the potentials of using VVAs in the classroom of childhood education as a teaching resource for science education? What needs come to cover these devices? How does the use of VVAs affect the role of the educator?

3 Conclusions
Students, analyze the different teaching uses that VVAs could have in the classroom of childhood education for science. Some of the conclusions they reached were the following:
• Stimulate oral communication since, with VVAs, can work communicative competence through the channel most suitable for one's age. This is essential so that children can express their ideas about natural phenomena.
• Be used as a source of information when researching in the classroom about a certain aspect of science that interests them to investigate.
• Use as a translator if a student who does not master the language of use is present in the classroom or you need a translation for some materials.
• Become an effective tool to accompany certain students who have special educational needs or even problems relating to their peers.
• Be search engines and narrators of oral resources for science education (stories,…).
The students concluded that the use of AVV can be very useful when considering the teaching of science in this educational stage. We believe that the use of AVVs can be a didactic tool that should be present in the science training of early childhood education teachers. For this reason, we are conducting a pilot study of its use in schools, where students in training train active teachers in its use.

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The Contribution of Physics Education Research in Educating Prospective Primary Teachers

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Abstract. Basic scientific education and teacher education are two interconnected problems studied in international educational research and physics education research, in particular. The Prospective Kindergarten and Primary Teacher education is a challenge for that scientific education competence that is able to promote children's critical thinking in an interpretative perspective in the exploration of phenomena and in building formal thought. The results of the last 20 years of research experimentation carried out at the University of Udine in the courses of Physics Education (DF) and Laboratory of Physics Education (LDF) in the third year of the five-year Master's program, that have produced the research-based consolidated formative model MEPS, are described in this article, including discussion of the different activities involved.

1. Introduction
   Extensive international studies have shown a lack of scientific education at all age levels [1], underlining the need for urgent actions connected to teaching professional education and development [2]. To focus on subject-related professional competence is an urgent challenge.
   The traditional models in teacher education, where pedagogical and subject-related education live in separate areas (in parallel or in sequence) leaving the integration to the prospective teacher is not working [3-4].
   The future primary teachers have to modify the traditional scientific education, which is sometimes vague and not very incisive, or, on the contrary, is structured in disciplinary and transmissive ways, unable to prefigure the cognitive role of the disciplines, due to a lack of epistemic and methodological attention, which produces mnemonic learning, with poor operational skills, which extinguishes curiosity and reduces the motivation of learners. For Prospective Primary Teachers (PPT) and scientific education, the problem includes three main questions: 1) the need to improve scientific education starting from early childhood [6]; 2) the lack of solid subject preparation of PPT; and 3) the lack of teaching tradition, instruments and methods for scientific education in kindergarten and primary school [7]. Few are the valid teaching supports on which PPT can count, such as textbooks, brochures, software: the available materials for scientific education often present concepts not related to each other, and not infrequently are plagued with methodological errors (and not only). In addition, physics has no didactic tradition at the basic school level and the interdisciplinarity in the scientific field is confused with the generic treatment in popular terms: the formative, methodological aspects and the identification of conceptual elements are completely neglected in textbooks. Physics notions appear in a fragmented way, without founding them in sense-making, while the relationship with mathematics is often treated in other chapters of the same textbook with examples taken by everyday life action without taking the opportunity to explore and interpret common phenomena.
   The PPT education is a research problem that goes beyond the integration of differentiated knowledge (Pedagogical and Subject matter knowledge), in favor of the appropriation of those competences that include how to organize teaching/learning path proposals, set up learning environments and activities, as well as knowing how to monitor and evaluate the learning process in the field, during classroom teaching. In Italy, the PPT education began in 2000 with a qualified project in a context unprepared for the task. This produced a research-based experimentation in the different universities [8]. The research-based characteristics and the results of the experimentation conducted in the Physics Education Course (DF) in the master's degree in Primary Science Education (SFP) of the University of Udine in the last 20 years are presented here.

2. Research
   For over twenty years, tools, methods and implementation models for the qualified professional education of future primary school teachers (PPT) are studied in the DF [5, 9, 10]. Research experimentation is carried out focusing on different aspects in PPT education [11-15]: 1) curricular contents and relative methods; 2) active role of PPT in their education; 3) instruments and methods; 4) role of planning; 5) integration of pedagogical, subject and transversal contribution in the master's degree; 6) curricular contributions to competence development and relative evaluation; 7) physics education research contributions; 8) role and impact of the school apprenticeship.
   The main research questions are:

3. How to produce familiarity in producing active scientific education in children starting from poor basic scientific knowledge?

4. How can planning educational paths produce competence in developing and evaluating learning scientific environments?

5. How can physics education research support the PPT education process?

3 Conclusion
Spontaneous teaching style of PPT is mutated by their experience in instruction, therefore is characterized by assertive presentation of notions and scarce involvement of learners: providing answers to questions not posed. Experiments are offered as observational news and interpretations of phenomena are not considered: the lack of relationship between science and math of textbooks is reproduced. The discussion of physics concepts in research-based educational paths produce familiarity with basic conceptual physics knowledge and offers examples of how to support learning experiences in pupils. This Metacultural educational activity is important in methodologic perspective change of PPT, but to gain awareness of the coherence in the educational paths discussed, they need Experiential experience by means of tutorials that they use in the same manner as their future learners: PPT have to experience the learning difficulties that pupils encounter in the learning process (RQ1). Planning educational paths is a useful exercise (RQ2), but can be a reductive reproduction of the research-based educational paths discussed as sequence of activities not well related with a poor attention to the learner role. We gain evidence of the need of the following phases: a) individual task in the perspective to work directly with children in school and attention to how to conduct each step; b) peer discussion in group of the path planned to reach an agreed Teaching Intervention Module (TIM); c) discussion in plenary with the responsible of the DF course of TIM and its revision; d) preparation of education materials for the TIM in classroom with children; e) prepare and use monitoring instruments and methods during the implementation of TIM; e) analysis of the learning process during the intervention; f) reflection with a peer observing the implementation the work done and report on the learning in the field (RQ2).
Physics education research supports each step in each topic of the PPT education (RQ3) and in particular offers: a) research-based science education paths; b) studies on learning difficulties in the different topics; c) tutorials on different topics; d) experiments and educational materials; e) reflection on educational aspects as the interplay between math and physics concepts, interdisciplinarity, role of metaphors, of representations, of exercise, of experiments and exploration…; f) self-evaluation by means of PCK exercises; g) instruments and methods for learning process analysis.
The MEPS model [5] integrating M-metacultural, E-experiential, P-planning and S-situated activities is developed. An important part of the appropriation of competence in science education by PPTs is the integration of the discussions of research-based educational paths, with the designed paths by PPTs, and the analysis of the teaching intervention modules (TIM) prepared by PPT [10]. The outcome of such work makes the acquired skills operational. The Situated learning, produced from the field experiences in real classes and from the monitoring and analysis of children's learning paths and outcomes consolidate the professional competences that are acquired.

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Physics in Swiss Primary Teacher Education: A Multidisciplinary Approach

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Abstract.
First, this paper overviews the curriculum organization of science teaching in Swiss primary schools. It becomes clear that science education in primary school is part of the integrated subject "nature-human-society," which includes different natural and social sciences disciplines. Second, the multidisciplinary approach in teacher training for the subject "nature-human-society" is described, and student teachers' views are shown, which makes evident that the different content areas of this integrated subject are not equally popular among student teachers.

1 Curriculum Organization of Science Teaching in Swiss Primary Schools

Physics does not appear in the primary school curriculum, but physical contents and practices are still part of primary education. Physics is missing as subject because the natural sciences are usually taught and learned through an integrated subject, namely, science, and not in a disciplinary way [1]. In Swiss primary schools, however, science class does not occur as a single subject, but in still further disciplines integrating subject [2]. Science is merged with humanities and social sciences in one subject, called "nature-human-society." Since the introduction in 2016 of the new, common curriculum for German-speaking Swiss Primary Schools and the associated redesign of this subject, "nature-human-society" comprises four content areas: (i) nature and technology, (ii) geography, history, and society, (iii) economics, work and housekeeping, and (iv) ethics, religions, and community. With this multidisciplinary curriculum, the "nature-human-society" lessons should support and encourage primary school pupils to explore and understand their natural, cultural, social, economic, and technical environment to act responsibly toward their living environment [3]. The approach should assure a multidimensional view of learning objects and thus avoid children accessing their living environment in a fragmented way [4].

2 Multidisciplinarity in Teacher Training and its Acceptance by Student Teachers

The special composition of the subject "nature-human-society" requires special teacher training, which brings the different content areas in the teacher program together without adding them up one after the other in only an isolated way. The training allows students to develop an appropriate understanding of the multidisciplinary subject matter and acquire the subject-integrated pedagogical content knowledge to plan and implement appropriate learning units [5]. At the Bern University of Teacher Education in Switzerland, several lecturers from different disciplines (biology, physics, geography, history, economics, religion, science, and ethics) interact to conceptualize the modules for teacher training in "nature-human-society." However, due to the great variety of subject content, not all content can be elaborated in detail in the three years of teacher training. Student teachers may at least gain insight into the most basic concepts of all perspectives [6]. A survey conducted at the Bern University of Teacher Education showed that the popularity of the different content areas is not equally pronounced among student teachers. Also within the field of natural sciences were clear differences. Most student teachers prefer biological and dislike physical or technical content [7–9]. Therefore, in a multidisciplinary subject like "nature-human-society," there is always the risk that some content will be neglected in favor of others. Thus, during teacher training, it is even more important that student teachers' interest in and beliefs about different disciplines are worked on to develop a professionally positive attitude toward all perspectives of the subject "nature-human-society".

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Innovation in Kindergarten and Primary School Teacher Education in Physical Sciences

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Innovation in Kindergarten and Primary School Teacher Education in Physical Sciences.

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Department of Physics, California Polytechnic State University at San Luis Obispo, USA

Description

Symposium
Innovation in Kindergarten and Primary School Teacher Education in Physical Sciences.

Responsibles:
Federico CORNI
Faculty of Education, Free University of Bozen-Bolzano (Italy)
Stamatis Vokos
Department of Physics, California Polytechnic State University at San Luis Obispo, USA

Introduction
Innovation in Primary Teacher Education in Physics is crucial at a time of rapid development of science and technology in society and in response to the growing need for a modern scientific preparation of new generations to help them to cope with future challenges. The four contributions in this symposium come from four very different settings, giving fertile ideas that have matured in different contexts. They are united by their grounding in scientific education and primary teacher education research and develop our theme from two relevant points of view, i.e., integration and technology. Two contributions present integrated approaches to teacher education: the first integrates metacultural, experiential, planning and situated activities, while the second integrates nature, human and social disciplines. The remaining two contributions deal with the need to include engineering design and ITC technologies in school and in teacher preparation.
This symposium is sponsored by the GIREP Thematic Group "Physics Preparation of Teachers in Grades K-6" in view of its interest in knowing and discussing promising strategies to professionally prepare a new generation of kindergarten and primary school teachers.

Description of presenters:
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José CANTO', Experimental and Social Sciences Teaching Department, University of Valencia (Spain).
Marisa MICHELINI, Research Unit in Didactics of Physics, University of Udine (Italy).
Angelika PAHL, Bern University of Teacher Education (Switzerland).

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Integrating Engineering into Physics for Future Teachers

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Abstract. In the United States, the Next Generation Science Standards calls for engineering — and particularly engineering design — to be part of students' science education throughout primary school, with engagement in engineering practices integrated into students' learning of disciplinary core ideas. We describe how opportunities for engineering emerge in the context of a course on scientific inquiry for future teachers, efforts to expand on those opportunities to better align with engineering design, and how these opportunities differ in important ways from more typical engineering design activities. In addition, we argue that engineering activities can support and sustain rich, meaningful inquiry.

1 Background
The Next Generation Science Standards (NGSS) [1] calls for engineering — and particularly engineering design — to be part of students' science education throughout K-12, with engagement in engineering practices integrated into students' learning of disciplinary core ideas. However, few prospective teachers have an engineering background, nor are they likely to receive even a cursory training in engineering while in their undergraduate degree program.
And while designed artifacts (labs, devices) are central to scientific activity — a critical component of how scientific ideas are constructed — curricular examples of engineering for science are rare. Instead, existing curricula that integrate science and engineering primarily treat engineering as an application of scientific theory or a way of engaging students and inspiring scientific questions (e.g., [2]). For programs that hope to prepare science teachers to integrate engineering design into the development of scientific content, in ways consistent with NGSS, there are few models to draw from.

2 About the course
The course described here [3] is taking steps to address this. Initially the course was developed prior to NGSS, when the "inquiry standards" stood alone; therefore we focused on students' constructing and vetting scientific explanations without explicit attention to the correctness of those models or a commitment to the particular content being addressed. While instructors selected a phenomenon to

launch our inquiry, this flexibility with content allows the course to be more responsive to questions that emerged. Topics varied, and included light, color, sound, astronomy, energy and time. Materials in the classroom varied as well, and are generally inexpensive, "everyday" materials (flashlights, plastic clocks), or "raw ingredients" (lenses, mirrors, inks, tape, string). These were available in the room or in an adjacent stockroom. When class is not in session, experiments were stored, not disassembled.
With the introduction of NGSS and engineering into primary and secondary education, we noticed the role played by designed artifacts in our course. Students frequently modify materials available, bring in new materials from home, deconstruct and reconstructing physical artifacts to support their inquiry. We identify these as rich moments to engage in purposeful engineering design. Below we briefly describe two exemplar moments. Our presentation will focus on these moments, efforts to capitalize on these for engineering design, and how they support and sustain engineering and scientific inquiry.
2.1 Opportunities for engineering
The two brief vignettes below describe how emergent questions sponsored opportunities for engineering design, which then informed our continued inquiry.
1. Absorption of light. As students in one course modeled shadows, a question emerged regarding the absorption of light: after how many reflections was our light too dim to be seen? One student constructed a kinked construction paper tube with a flashlight at one end. By placing the kinks so that she could no longer see the flashlight bulb, she was able to determine that, after 4 reflections, light from the bulb was essentially all absorbed (for black paper; 6 for white).
2. Measuring speed. In a semester focused on energy, students were using a Gaussian Gun to model energy transfers and transformations [4]. A debate arose as to whether the magnet itself provided energy to the ball; to resolve this students needed to measure that speed – for a ball accelerating rapidly over a very short distance. Among the more creatively engineered methods was the 3-d printing of a surface on which the balls would roll so they could record the sound and, from this, determine speed.

3 Conclusion
This presentation describes how opportunities to engage in meaningful engineering emerge in scientific inquiry, and how we have capitalized on those moments to support engineering and sustain the inquiry as well.

Acknowledgements
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The virtual voice assistants in early science learning: an opportunity in Early Childhood Education
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2 Advisor to the Child Education Training Center - Generalitat Valenciana (Spain).

Abstract. Technology is present in our lives and is also increasingly present in the classroom, as an educational tool. This fact must also have its transposition in the initial teacher training. This contribution presents a work in which virtual voice assistants are introduced as a tool in the teaching of science in early childhood education. We want to show the ideas from a group of 40 future teachers in their last year of the Degree, about the usefulness and the didactical possibilities of using virtual voice assistants as a tool in the teaching of science in early childhood education.

1 Introduction
In recent years, the common use of Information and Communications Technology (ICT), artificial intelligence and robots has spread across all educational stages including Early Childhood Education [1]. Consequently, children are exposed to digital devices from an early age. In addition, it has been proven that students work well in these digital contexts and even enjoy their use and the fact that

they can speak directly to the machines [2] [3]. In this way it is not strange that in the educational field, we find that robots have been used as classroom assistants [4], or that they are even used as a tool to meet special needs in the classroom such as functional diversity or autism [5]. In this work we intend to reflect upon and investigate the usefulness of a particular multimedia resource that, for the time being, has not expanded into classrooms like those mentioned above: virtual voice assistants (VVAs).
Some works [6] [7] showed that VVA can have a greater impact on a child's cognitive development than when interacting with other devices such as computers or smartphones. In addition, they can also serve to modify many social dynamics both in the school environment and in the family environment. The key to the use of VVAs in Early Childhood Education for science is that the user interface is oral and is therefore accessible to children at this educational stage. To this, we must add that there have been significant improvements in current VVAs regarding the so-called error rate when specific questions are asked that allow a more fluid interaction with them. In this perspective, VVAs can be an effective tool to develop the potential of younger children while becoming a facilitator element for the teacher and allowing for autonomous learning. Other advantages of its use are its ease of installation (it only requires a power outlet and internet connection), its low economic cost, as well as the diversity of models available on the market (Amazon's Alexa, Apple's Siri, Google voice search…).

2 Methodology

Through focus group work, 40 students in the last year of the Infant Education Teacher degree at the University of Valencia (Spain) have reflected on the possibilities of using virtual voice assistants as a tool for teaching science in early childhood education. They have to address some questions, such as: What are the potentials of using VVAs in the classroom of childhood education as a teaching resource for science education? What needs come to cover these devices? How does the use of VVAs affect the role of the educator?

3 Conclusions

Students, analyze the different teaching uses that VVAs could have in the classroom of childhood education for science. Some of the conclusions they reached were the following:

- Stimulate oral communication since, with VVAs, can work communicative competence through the channel most suitable for one's age. This is essential so that children can express their ideas about natural phenomena.
- Be used as a source of information when researching in the classroom about a certain aspect of science that interests them to investigate.
- Use as a translator if a student who does not master the language of use is present in the classroom or you need a translation for some materials.
- Become an effective tool to accompany certain students who have special educational needs or even problems relating to their peers.
- Be search engines and narrators of oral resources for science education (stories,…).

The students concluded that the use of AVV can be very useful when considering the teaching of science in this educational stage. We believe that the use of AVVs can be a didactic tool that should be present in the science training of early childhood education teachers. For this reason, we are conducting a pilot study of its use in schools, where students in training train active teachers in its use.

Acknowledgements
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The Contribution of Physics Education Research in Educating Prospective Primary Teachers
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Abstract. Basic scientific education and teacher education are two interconnected problems studied in international educational research and physics education research, in particular. The Prospective Kindergarten and Primary Teacher education is a challenge for that scientific education competence that is able to promote children's critical thinking in an interpretative perspective in the exploration of phenomena and in building formal thought. The results of the last 20 years of research experimentation carried out at the University of Udine in the courses of Physics Education (DF) and Laboratory of Physics Education (LDF) in the third year of the five-year Master's program, that have produced the research-based consolidated formative model MEPS, are described in this article, including discussion of the different activities involved.

1. Introduction
   Extensive international studies have shown a lack of scientific education at all age levels [1], underlining the need for urgent actions connected to teaching professional education and development [2]. To focus on subject-related professional competence is an urgent challenge.
   The traditional models in teacher education, where pedagogical and subject-related education live in separate areas (in parallel or in sequence) leaving the integration to the prospective teacher is not working [3-4].
   The future primary teachers have to modify the traditional scientific education, which is sometimes vague and not very incisive, or, on the contrary, is structured in disciplinary and transmissive ways, unable to prefigure the cognitive role of the disciplines, due to a lack of epistemic and methodological attention, which produces mnemonic learning, with poor operational skills, which extinguishes curiosity and reduces the motivation of learners. For Prospective Primary Teachers (PPT) and scientific education, the problem includes three main questions: 1) the need to improve scientific education starting from early childhood [6]; 2) the lack of solid subject preparation of PPT; and 3) the lack of teaching tradition, instruments and methods for scientific education in kindergarten and primary school [7]. Few are the valid teaching supports on which PPT can count, such as textbooks, brochures, software: the available materials for scientific education often present concepts not related to each other, and not infrequently are plagued with methodological errors (and not only). In addition, physics has no didactic tradition at the basic school level and the interdisciplinarity in the scientific field is confused with the generic treatment in popular terms: the formative, methodological aspects and the identification of conceptual elements are completely neglected in textbooks. Physics notions appear in a fragmented way, without founding them in sense-making, while the relationship with mathematics is often treated in other chapters of the same textbook with examples taken by everyday life action without taking the opportunity to explore and interpret common phenomena.
   The PPT education is a research problem that goes beyond the integration of differentiated knowledge (Pedagogical and Subject matter knowledge), in favor of the appropriation of those competences that include how to organize teaching/learning path proposals, set up learning environments and activities, as well as knowing how to monitor and evaluate the learning process in the field, during classroom teaching. In Italy, the PPT education began in 2000 with a qualified project in a context unprepared for the task. This produced a research-based experimentation in the different universities [8]. The research-based characteristics and the results of the experimentation conducted in the Physics Education Course (DF) in the master's degree in Primary Science Education (SFP) of the University of Udine in the last 20 years are presented here.

2. Research
   For over twenty years, tools, methods and implementation models for the qualified professional education of future primary school teachers (PPT) are studied in the DF [5, 9, 10]. Research experimentation is carried out focusing on different aspects in PPT education [11-15]: 1) curricular

contents and relative methods; 2) active role of PPT in their education; 3) instruments and methods; 4) role of planning; 5) integration of pedagogical, subject and transversal contribution in the master's degree; 6) curricular contributions to competence development and relative evaluation; 7) physics education research contributions; 8) role and impact of the school apprenticeship.
The main research questions are:

3. How to produce familiarity in producing active scientific education in children starting from poor basic scientific knowledge?
4. How can planning educational paths produce competence in developing and evaluating learning scientific environments?
5. How can physics education research support the PPT education process?

3 Conclusion
Spontaneous teaching style of PPT is mutated by their experience in instruction, therefore is characterized by assertive presentation of notions and scarce involvement of learners: providing answers to questions not posed. Experiments are offered as observational news and interpretations of phenomena are not considered: the lack of relationship between science and math of textbooks is reproduced. The discussion of physics concepts in research-based educational paths produce familiarity with basic conceptual physics knowledge and offers examples of how to support learning experiences in pupils. This Metacultural educational activity is important in methodologic perspective change of PPT, but to gain awareness of the coherence in the educational paths discussed, they need Experiential experience by means of tutorials that they use in the same manner as their future learners: PPT have to experience the learning difficulties that pupils encounter in the learning process (RQ1). Planning educational paths is a useful exercise (RQ2), but can be a reductive reproduction of the research-based educational paths discussed as sequence of activities not well related with a poor attention to the learner role. We gain evidence of the need of the following phases: a) individual task in the perspective to work directly with children in school and attention to how to conduct each step; b) peer discussion in group of the path planned to reach an agreed Teaching Intervention Module (TIM); c) discussion in plenary with the responsible of the DF course of TIM and its revision; d) preparation of education materials for the TIM in classroom with children; e) prepare and use monitoring instruments and methods during the implementation of TIM; e) analysis of the learning process during the intervention; f) reflection with a peer observing the implementation the work done and report on the learning in the field (RQ2).
Physics education research supports each step in each topic of the PPT education (RQ3) and in particular offers: a) research-based science education paths; b) studies on learning difficulties in the different topics; c) tutorials on different topics; d) experiments and educational materials; e) reflection on educational aspects as the interplay between math and physics concepts, interdisciplinarity, role of metaphors, of representations, of exercise, of experiments and exploration…; f) self-evaluation by means of PCK exercises; g) instruments and methods for learning process analysis.
The MEPS model [5] integrating M-metacultural, E-experiential, P-planning and S-situated activities is developed. An important part of the appropriation of competence in science education by PPTs is the integration of the discussions of research-based educational paths, with the designed paths by PPTs, and the analysis of the teaching intervention modules (TIM) prepared by PPT [10]. The outcome of such work makes the acquired skills operational. The Situated learning, produced from the field experiences in real classes and from the monitoring and analysis of children's learning paths and outcomes consolidate the professional competences that are acquired.

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Physics in Swiss Primary Teacher Education: A Multidisciplinary Approach

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Abstract.
First, this paper overviews the curriculum organization of science teaching in Swiss primary schools. It becomes clear that science education in primary school is part of the integrated subject "nature-human-society," which includes different natural and social sciences disciplines. Second, the multidisciplinary approach in teacher training for the subject "nature-human-society" is described, and student teachers' views are shown, which makes evident that the different content areas of this integrated subject are not equally popular among student teachers.

1 Curriculum Organization of Science Teaching in Swiss Primary Schools

Physics does not appear in the primary school curriculum, but physical contents and practices are still part of primary education. Physics is missing as subject because the natural sciences are usually taught and learned through an integrated subject, namely, science, and not in a disciplinary way [1]. In Swiss primary schools, however, science class does not occur as a single subject, but in still further disciplines integrating subject [2]. Science is merged with humanities and social sciences in one subject, called "nature-human-society." Since the introduction in 2016 of the new, common curriculum for German-speaking Swiss Primary Schools and the associated redesign of this subject, "nature-human-society" comprises four content areas: (i) nature and technology, (ii) geography, history, and society, (iii) economics, work and housekeeping, and (iv) ethics, religions, and community. With this multidisciplinary curriculum, the "nature-human-society" lessons should support and encourage primary school pupils to explore and understand their natural, cultural, social, economic, and technical environment to act responsibly toward their living environment [3]. The approach should assure a multidimensional view of learning objects and thus avoid children accessing their living environment in a fragmented way [4].

2 Multidisciplinarity in Teacher Training and its Acceptance by Student Teachers

The special composition of the subject "nature-human-society" requires special teacher training, which brings the different content areas in the teacher program together without adding them up one after the other in only an isolated way. The training allows students to develop an appropriate understanding of the multidisciplinary subject matter and acquire the subject-integrated pedagogical content knowledge to plan and implement appropriate learning units [5]. At the Bern University of Teacher Education in Switzerland, several lecturers from different disciplines (biology, physics, geography, history, economics, religion, science, and ethics) interact to conceptualize the modules for teacher training in "nature-human-society." However, due to the great variety of subject content, not all content can be elaborated in detail in the three years of teacher training. Student teachers may at least gain insight into the most basic concepts of all perspectives [6]. A survey conducted at the Bern University of Teacher Education showed that the popularity of the different content areas is not equally pronounced among student teachers. Also within the field of natural sciences were clear differences. Most student teachers prefer biological and dislike physical or technical content [7–9]. Therefore, in a multidisciplinary subject like "nature-human-society," there is always the risk that some content will be neglected in favor of others. Thus, during teacher training, it is even more important that student teachers' interest in and beliefs about different disciplines are worked on to develop a professionally positive attitude toward all perspectives of the subject "nature-human-society".

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Collaborative Activities for University Physics during COVID and for post-COVID Times

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An active-learning workshop is offered to provide examples of a collaborative group-learning pedagogical environment for introductory physics at the university level. Participants will engage in various hands-on and minds-on activities that will illustrate how such a dynamic classroom can transform the strategy for teaching physics in university classes. A discussion about the benefits and challenges will help guide the participants in adopting this teaching method in their own physics classes, either in online mode or for in-person instruction.

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Strategies for Active Learning and Assessment of the Learning Processes

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Abstract. Active Learning strategies are acknowledged to improve student understanding in many disciplinary fields. However, both the shift in learning objectives due to the use of these strategies and the recent need to implement active learning taking into account the requirements of mixed-mode teaching due to the COVID-19 pandemic pose the problem of developing and validating new assessment methods and techniques. In this Symposium, both examples of active learning activities focused on developing critical reasoning skills, like modelling and argumentation, and of assessment tools and methods will be presented and discussed.

1 Introduction to the Symposium
Active learning methods and strategies are credited with improving student conceptual understanding in many fields, including physics [e.g. 1-2]. This is possibly due to the strongly contextualized nature of active learning education, that emphasises on the interdependence of situation and cognition. When learning and context are put together, knowledge is seen by learners as a tool to be used dynamically to solve problems and develop critical reasoning, processes and transversal skills, rather than the final product of education.
In recent years, some innovative teaching and learning based on mixed mode real-virtual laboratories and model building, enhanced by the use of digital technologies, and aimed at actively involving students in their learning processes even remotely, has been conducted. This was further motivated by specific requests for distance learning coming from schools and universities due to the COVID-19 pandemic.
However, with the shift in teaching modes due to the pandemic and with learning objectives spefically related to active learning, focused on the development of skills and processes, the approach to assessment needs to change. New assessment techniques to review the entire learning process and determine the effectiveness of the active-learning approaches proposed to the students need to be developed and validated, [3].
The four talks part of this symposium will deal with the implementation of innovative active learning strategies, focused on hands-on and minds-on activities, on mixed-mode distance teaching, and on the activation of modelling and problem solving processes to actively engage and involve the students. The development and use of formative and summative assessment tools will also be discussed.
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Constructing a deeper meaning through modelling

Abstract. My talk will describe my work in modelling and in particular, the connection between modelling and problem solving. Key to the theory of modelling is the realization that modelling

is a natural activity. We form mental models to understand a problem and the construction of a mathematical models is, in essence, an extension of this kind of natural cognitive activity. That said, modelling is not an easy skill to acquire. Modelling is best regarded as a constructivist activity in which students actively participate in the construction of meaning. It is best undertaken in groups as a form of guided enquiry.

1 Introduction
In this talk I will describe my work in modelling [1] and in particular, the connection between modelling and problem solving. A key step in teaching students how to build models is the recognition that in order to solve a problem we have to build an internal, or mental, model of the problem. This kind of modelling is a natural activity. It is a key part of reasoning and the development of a mental model of the problem leads naturally to a potential solution and the construction of mathematical model. In short, building models is, in essence, no different from the kinds of cognitive activities we undertake every day and in this presentation I will elucidate this idea.
I will argue that models are causal or explanatory mechanisms built from concepts which in turn lead to the formation of new concepts. Concepts are here regarded as embodying relationships of one kind or another. These relationships can be causal, such as the relationship between a force and acceleration, temporal, such as the relationship between change in position with time, spatial, implying the use of vectors, for example, or probabilistic. It follows that in order to build a model, students need to understand a system. They need to be able to identify objects, such as masses and charges, and understand the nature of their interactions and relationships with other elements of the system. They need to be able to recognise the various forces present as well as their consequences.
Modelling is a constructivist activity. The act of building a model not only requires the modeller to recognise and use physics knowledge, as described above, the very act of modelling is a way of actively applying knowledge and thereby deepening understanding. However, there is a good chance that students either will not have encountered all the necessary physics or, if they have, that they will not understand it sufficiently to be able to use it effectively. Therefore, it is necessary to use problems that lie within the zone of proximal development, which, as defined by Vygotsky, is that space between what they can do unaided and what they can do with guidance and prompting. Providing guidance and prompting to ensure that students develop an effective model is thus essential to modelling as a method of active learning. It helps to ensure that students can actually build the models required to solve the problem and in so doing help them gain confidence in the process. However, as students develop at different rates and will need different amounts of guidance, it is best if models are built within groups so that students can exchange ideas and use their collective knowledge to understand the system and develop the model.
The process of building a model itself comprises three different, but not always distinct, stages. The first stage has been described above and involves developing a qualitative, mental model of the system. The second stage involves translating this understanding to a mathematical formulism and the third stage involves “running” the model and evaluating the outcome against the initial assumptions and expectations. Running the model does not mean running computer code, but developing the mathematics and solving the equations for the particular circumstances set out in the problem. Limiting cases or particular approximations might also be examined to test the validity of the model.
Modelling can thus be regarded as a process of making sense of the physical world and this connection with sensemaking is important. It is well documented that many students will approach simple problems as an exercise in finding the right equation to apply. They appear to lack an insight into the origin and meaning of the equations they seek, that they arise out of this process and reflect a physical reality. Modelling is a process by which this connection between physics and mathematics is revealed and strengthened.
The process of translating from physics to mathematics and back again is taken for granted by professional physicists and poorly understood by educators who would like to teach students how to develop this skill. I will argue in this talk that modelling is a natural way to do this. I will argue that the development of iconic, analogical, qualitative mental models is a natural process and perhaps the dominant mode of reasoning in humans. I will further argue that many concepts imply mathematical relationships and that developing a mathematical description of a physical system follows naturally from a description of the system in terms of the basic concepts.
In this talk, the whole modelling sequence, from understanding a problem, to constructing a mathematical description and assessing the outcomes of the model, will be described along with guidance on how to implement this kind of approach within a class. It will be shown that translating between representations is key to this sequence and that an effective way of assessing modelling activities is to concentrate on the use of representations and in particular, the translation from one representa-

tion to another as students pass through the different stages of modelling.

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The physics of color, and its digital modeling, explored through a real remote laboratory (RRL) learning path.

Abstract. During the pandemic, a remote learning experience based on a mixed mode real-virtual laboratory, was conducted to respond to specific requests for distance learning coming from secondary schools. The peculiarity of this type of learning activity requires evaluation and assessment methods specifically taking into account the mixed real/virtual nature of lab activities and the purely virtual nature of the interaction among learners and between them and the teacher. In this contribution, some proposals will be presented and discussed, for the evaluation of learning outcomes and the assessment of both the learning process and in the aim of providing students with self evaluation tools.

The COVID-19 pandemic crisis, by suddenly requiring a shift of learning activities in remote mode, has hardly challenged the effectiveness of distance learning methodologies [1], especially in contexts where laboratorial activities play a central role. In fact, in emergencies, virtual laboratory (VL) is a substitute for the real laboratory (RL) [2, 3], as are the real experiments made with easily available materials, self-prepared by learners at home. However, the RL remains irreplaceable, especially in didactic setups relying on investigation-based laboratorial methods [4-5]. Despite its importance, the conventional RL is sometimes not available, as for example in the case of distance learning activities. In such cases, a possible substitute could be the "real remote laboratory" (RRL), where students run real experiments by remotely accessing true experimental apparatuses [6-7].
In this context, and in response to requests for training from local schools in Calabria (Italy), in the academic year 20/21 an RRL initiative of an innovative nature was designed and implemented, within an Italian national program (PCTO) aimed at fostering the transversal skills of high school students and at developing their specific knowledge and skills useful for adequately choosing the post-secondary training path. Since a distinctive feature of the PCTO program is to offer students the opportunity to participate in educational activities within a real working context, the learning path was framed within the research activities of the Laboratory of Applied Physics for Cultural Heritage at the University of Calabria, with particular reference to spectroscopic and colorimetric techniques applied to the conservative diagnostic of fine arts [8]. RRLs proposed in the literature (e.g. [6-7]) are very well-designed and useful, but require a considerable technical infrastructure, including some kind of physical control interface for the apparatus in the lab, and a software user interface to remotely access the apparatus. This means that such a kind of RRL cannot be set up extemporaneously to quickly respond to specific distance learning needs, as it happened during the Covid-19 pandemic. To address these limitations, we have devised and tested a different paradigm of RRL, structured as follows: (i) students are introduced to the problem and an inquiry-oriented experimental strategy is outlined; (ii) a human instructor executes the real experiments in the laboratory, while students are participating in video streaming from home; (iii) the experimentally acquired raw data are transmitted to students, who (iv) process them and, if necessary, ask the instructor for the possible execution of subsequent measurements, which will be performed in a subsequent session in real time. Finally (v) information obtained from data processing are cooperatively discussed and conclusions are drawn. The learning activity is enriched by elements of web-mediated real time interaction, on the model of interactive lecture demonstrations [9], and all interactions among players (single students, university instructor, school tutors) are performed in video conference mode. The physics of the color, and its digital representation and processing, is the topic on which the learning path is contextualized, with particular reference to the modeling through color spaces, as the RGB model. The real experimental activities consist of various reflectance spectroscopy measurements on standard pictorial pigments, in order to investigate the relationship between perceived color and spectral shape of the reflected light. Moreover, the false-color processing method [10] has been introduced, to characterize pigments, discriminating between like-appearing colors corresponding to different spectral composition (methamerism).
In this contribution, after presenting the RRL learning path, a particular attention is devoted to the assessment-related issues. In fact, the peculiarity of this type of learning activity requires evaluation and assessment methods specifically considering the mixed real/virtual nature of lab activities

and the purely virtual nature of the interaction among learners and between them and the teacher. Furthermore, given the orientation purpose covered by the learning activity, we discuss what kind of assessment (appropriate for distance learning with particular reference to RRL) is able to provide students with suitable vocational feedback, in order to help them orientate for post-secondary instruction. Attention will be paid to the evaluation of learning outcomes and to the assessment of the learning process, also in the aim of providing students with self-evaluation tools. An attempt will be made to compare the results obtained, with some works that have appeared in the literature in the meantime [1].

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How to help teachers to implement active learning strategies enhanced by formative assessment tools

Abstract. A large nunber of inquiry activities with teaching and learning materials has been developed within the national project IT Academy (2016-2022) implementing design-based research. They are designed respecting the principles of active learning, inquiry approach, digital technologies and formative assessment. The activities were trialed in the classroom in two subsequent cycles. Based on teachers´ feedback collected with the help of a questionnare the materials were modified to get the final improved version. In the paper we present the research design as well as examples of developed activities at different levels of inquiry with suggested formative assessment tools.

1 Introduction
Active learning and inquiry-based approaches place student at the centre of the learning experience. In inquiry-based science education (IBSE) students are searching for an answer to a driving question working within a specific framework similar way as scientists do. There have been large effort invested in the implementation of IBSE as well as formative assessment tools. A number of European projects has been dealing with these issues, such as ESTABLISH, FIBONACCI, CHREACT or ASSIST-ME [1-5]. They motivated project partners to continue in these efforts at national levels. In Slovakia, large national project IT Academy has been running since 2016 [6]. Its main goals emerged from the imbalance between the current goals of the curriculum emphasizing IBSE and lack of instructional materials. As a result, one of the main goals is to support education by developing teaching and learning materials based on IBSE approaches enhanced by digital technologies and formative assessment tools.

2 Methodology
In order to achieve the main project goals, design-based research has been implemented. A number of experts in the field of physics education designed teaching and learning materials respecting the agreed criteria. Each lesson has been designed at a certain level of inquiry [7] starting with a driving question respecting the 5E learning cycle model [8] and is complemented with formative assessment tools. The materials were implemented in the classroom in two subsequent cycles. In each round they were reviewed by at least five teachers. Their feedback was collected leading to the updated version. The second trialing resulted in the final version of the materials that are presented online for a wide use of teachers and students.

3 Results
In physics, 80 lesson plans for upper and 78 lesson plans for lower secondary schools have been developed with materials for teachers and students (worksheets, exemplary filled-in worksheets for teachers, computer files, and other complementary materials). The important element of the lesson plan was the use of formative assessment tools. In the following we present examples of activities grouped on the basis of the specific formative assessment tool.
a. Making predictions as a natural part of the inquiry activities
The Predict – observe – explain strategy is used almost in every activity to predict the outcomes of an experiment. Predictions are compared with the experimental results and students´ explanations are explored in order to uncover their ideas. In the activity on law of momentum conservation, students predict velocity, momentum and total momentum of carts.
b. Peer assessment in project-based learning
In this activity students in groups work on the assigned research problems. At the end they hand in the project report with detailed description of the project goals, experimental design, data collection, their analysis and interpretation and conclusions. After that each group is assigned to review two other groups´ projects for evaluation and they fill-in the evaluation report. All reports are also commented by teacher who summarize results for the whole class.
c. Self-assessment as a strategy to reflect on own student´s learning
Many activites are complemented with self-evaluation sheets that make students to think about their own learning. At the same time it provides feedback to teacher. In the activity on Faraday´s law of electromagnetic induction students investigate the voltage induced in a coil situated between the poles of a turning horseshoe magnet. They analyze the experimental results for different parameters (frequency and number of coil turns) and reflect on the concepts and skills understanding in the self-evaluation sheet.

4 Conclusion
The experience from the implementation shows that teachers still need training in the field of IBSE and formative assessment strategies to fully understand their purpose and how to adjust teaching based on their implementation. We have designed online teacher education webinars where these issues are presented and discussed in detail.

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Strategies for Assessment of Inquiry Learning in Science

Abstract. Active learning methods receiving more and more attention require a design of assessment methods tailored to their goals and evaluation of the entire learning process. In the SAILS project, 19 science learning units in the inquiry-based learning approach were designed together with the whole spectrum of assessment tools. Each unit was tested in 3-8 classes, and the teachers reported their experiences in case studies. Teachers proved to be able to conduct the IBL lessons and use the assessment tools designed for formative assessment, however, their preferences for evaluation differed.

1 Introduction
In the last few decades, active learning methods have been receiving more and more attention as the best approaches to developing XXI-century skills. Unlike traditional methods, which are the most effective in delivering content knowledge at low levels of Bloom's taxonomy, active learning methods support developing competencies in their holistic form, comprising content knowledge, skills, and attitudes. They transform the classroom into a student-centered environment, in which students engaged collaboratively [1], discover the world by inquiry [2], and thus create their own learning paths. However, when active learning methods replace the traditional teaching approach, standard evaluation focusing only on content knowledge becomes inadequate. The mindset for assessment needs to change from standardized tests to the assessment tools evaluating the entire learning process, also during this process. So next to the summative assessment, a lot of teacher attention should be devoted to formative assessment. Such an approach has tremendous power in learning - as found by Black and William in their meta-analysis [3], intentional use of evaluation in the classroom (formative assessment) to promote learning unequivocally improved student achievements.

2 Inquiry-based learning and assessment
Inquiry-based learning (IBL) has been one of the most advocated active learning methods in science education over the last two decades is [4]. It leads to knowledge and understanding of the world by asking inquiry questions, formulating hypotheses, and testing them by collecting data during scientific experiments and using them as evidence to explain phenomena or events. In general, learning by inquiry follows a research cycle the researchers employ when they study a scientific problem. The concept of this pedagogy is not new; however, its educational potential has been increasing in technology-based societies [2]. It has been associated with increased students' motivation and interest in science, supporting the development of inquiry competencies and conceptual understanding [5].
As in any other learning environments and teaching/learning strategies, assessment in the IBL involves a collection of data, its analysis, formulation of conclusions and a feedback given to the students. Formative assessment (also called 'assessment for learning' [6]) serves the improvement of the learning process and is linked to the instant feedback given to students during this process. It can become relatively informal through on-the-fly interactions (informal formative assessment conversations [7]) or can be implemented more formally – with the help of evaluation tools and assessment plans prepared in advance (e.g., rubrics [8]). However, if used in the IBL approach, it should also reflect the goals and nature of this pedagogy [9-10].

3 Research and results
During the SAILS EU project [11], 19 science learning units in the IBL pedagogy were designed together with many ready-to-use assessment tools embedded into the material. More than 2500 teachers in 12 countries participated in SAILS teacher education programs with the IBL practical training based on the developed material. Each unit was implemented by 3-8 teachers and reported as case studies. The assessment focused on a particular set of inquiry skills and competencies in every learning unit was proposed and associated with recommended evaluation tools. Brainstorming and classroom dialogue were assessed using checkboxes (Electricity unit) and less formally (on-the-fly) in most other units. In half of the units, teachers implemented self- and peer-assessment tools for the evaluation of collaborative work. Worksheets and other student-devised material were evaluated with rubrics in almost all cases. In one-third of case studies, teachers collected their assessment data in observations.
Most of the teachers followed the units and assessment strategies proposed in the ready-to-use materials, and a few of them willingly adapted units or assessment tools to their purposes. In general, the frequency of implementation of the assessment methods spoke for teachers' preferences. A closer look (e.g., Electricity unit) into case studies revealed that some of them felt uncomfortable with the evaluation tools the others reported as favorable.
So, the conclusion is that, when designing teaching materials user-friendly and beneficial for as many classes as possible, a broad spectrum of assessment opportunities should be included, both for formative and summative evaluation of the IBL approach.

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Strategies for Active Learning and Assessment of the Learning Processes

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Abstract. Active Learning strategies are acknowledged to improve student understanding in many disciplinary fields. However, both the shift in learning objectives due to the use of these strategies and the recent need to implement active learning taking into account the requirements of mixed-mode teaching due to the COVID-19 pandemic pose the problem of developing and validating new assessment methods and techniques. In this Symposium, both examples of active learning activities focused on developing critical reasoning skills, like modelling and argumentation, and of assessment tools and methods will be presented and discussed.

1 Introduction to the Symposium
Active learning methods and strategies are credited with improving student conceptual understanding in many fields, including physics [e.g. 1-2]. This is possibly due to the strongly contextualized nature of active learning education, that emphasises on the interdependence of situation and cognition. When learning and context are put together, knowledge is seen by learners as a tool to be used dynamically to solve problems and develop critical reasoning, processes and transversal skills,

rather than the final product of education.
In recent years, some innovative teaching and learning based on mixed mode real-virtual laboratories and model building, enhanced by the use of digital technologies, and aimed at actively involving students in their learning processes even remotely, has been conducted. This was further motivated by specific requests for distance learning coming from schools and universities due to the COVID-19 pandemic.
However, with the shift in teaching modes due to the pandemic and with learning objectives spefically related to active learning, focused on the development of skills and processes, the approach to assessment needs to change. New assessment techniques to review the entire learning process and determine the effectiveness of the active-learning approaches proposed to the students need to be developed and validated, [3].
The four talks part of this symposium will deal with the implementation of innovative active learning strategies, focused on hands-on and minds-on activities, on mixed-mode distance teaching, and on the activation of modelling and problem solving processes to actively engage and involve the students. The development and use of formative and summative assessment tools will also be discussed.
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Constructing a deeper meaning through modelling

Abstract. My talk will describe my work in modelling and in particular, the connection between modelling and problem solving. Key to the theory of modelling is the realization that modelling is a natural activity. We form mental models to understand a problem and the construction of a mathematical models is, in essence, an extension of this kind of natural cognitive activity. That said, modelling is not an easy skill to acquire. Modelling is best regarded as a constructivist activity in which students actively participate in the construction of meaning. It is best undertaken in groups as a form of guided enquiry.

1 Introduction
In this talk I will describe my work in modelling [1] and in particular, the connection between modelling and problem solving. A key step in teaching students how to build models is the recognition that in order to solve a problem we have to build an internal, or mental, model of the problem. This kind of modelling is a natural activity. It is a key part of reasoning and the development of a mental model of the problem leads naturally to a potential solution and the construction of mathematical model. In short, building models is, in essence, no different from the kinds of cognitive activities we undertake every day and in this presentation I will elucidate this idea.
I will argue that models are causal or explanatory mechanisms built from concepts which in turn lead to the formation of new concepts. Concepts are here regarded as embodying relationships of one kind or another. These relationships can be causal, such as the relationship between a force and acceleration, temporal, such as the relationship between change in position with time, spatial, implying the use of vectors, for example, or probabilistic. It follows that in order to build a model, students need to understand a system. They need to be able to identify objects, such as masses and charges, and understand the nature of their interactions and relationships with other elements of the system. They need to be able to recognise the various forces present as well as their consequences.
Modelling is a constructivist activity. The act of building a model not only requires the modeller to recognise and use physics knowledge, as described above, the very act of modelling is a way of actively applying knowledge and thereby deepening understanding. However, there is a good chance that students either will not have encountered all the necessary physics or, if they have, that they will not understand it sufficiently to be able to use it effectively. Therefore, it is necessary to use problems that lie within the zone of proximal development, which, as defined by Vygotsky, is that space between what they can do unaided and what they can do with guidance and prompting. Providing guidance and prompting to ensure that students develop an effective model is thus essential to modelling as a method of active learning. It helps to ensure that students can actually build the models required to solve the problem and in so doing help them gain confidence in the process.

However, as students develop at different rates and will need different amounts of guidance, it is best if models are built within groups so that students can exchange ideas and use their collective knowledge to understand the system and develop the model.
The process of building a model itself comprises three different, but not always distinct, stages. The first stage has been described above and involves developing a qualitative, mental model of the system. The second stage involves translating this understanding to a mathematical formulism and the third stage involves "running" the model and evaluating the outcome against the initial assumptions and expectations. Running the model does not mean running computer code, but developing the mathematics and solving the equations for the particular circumstances set out in the problem. Limiting cases or particular approximations might also be examined to test the validity of the model. Modelling can thus be regarded as a process of making sense of the physical world and this connection with sensemaking is important. It is well documented that many students will approach simple problems as an exercise in finding the right equation to apply. They appear to lack an insight into the origin and meaning of the equations they seek, that they arise out of this process and reflect a physical reality. Modelling is a process by which this connection between physics and mathematics is revealed and strengthened.
The process of translating from physics to mathematics and back again is taken for granted by professional physicists and poorly understood by educators who would like to teach students how to develop this skill. I will argue in this talk that modelling is a natural way to do this. I will argue that the development of iconic, analogical, qualitative mental models is a natural process and perhaps the dominant mode of reasoning in humans. I will further argue that many concepts imply mathematical relationships and that developing a mathematical description of a physical system follows naturally from a description of the system in terms of the basic concepts.
In this talk, the whole modelling sequence, from understanding a problem, to constructing a mathematical description and assessing the outcomes of the model, will be described along with guidance on how to implement this kind of approach within a class. It will be shown that translating between representations is key to this sequence and that an effective way of assessing modelling activities is to concentrate on the use of representations and in particular, the translation from one representation to another as students pass through the different stages of modelling.

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The physics of color, and its digital modeling, explored through a real remote laboratory (RRL) learning path.

Abstract. During the pandemic, a remote learning experience based on a mixed mode real-virtual laboratory, was conducted to respond to specific requests for distance learning coming from secondary schools. The peculiarity of this type of learning activity requires evaluation and assessment methods specifically taking into account the mixed real/virtual nature of lab activities and the purely virtual nature of the interaction among learners and between them and the teacher. In this contribution, some proposals will be presented and discussed, for the evaluation of learning outcomes and the assessment of both the learning process and in the aim of providing students with self evaluation tools.

The COVID-19 pandemic crisis, by suddenly requiring a shift of learning activities in remote mode, has hardly challenged the effectiveness of distance learning methodologies [1], especially in contexts where laboratorial activities play a central role. In fact, in emergencies, virtual laboratory (VL) is a substitute for the real laboratory (RL) [2, 3], as are the real experiments made with easily available materials, self-prepared by learners at home. However, the RL remains irreplaceable, especially in didactic setups relying on investigation-based laboratorial methods [4-5]. Despite its importance, the conventional RL is sometimes not available, as for example in the case of distance learning activities. In such cases, a possible substitute could be the "real remote laboratory" (RRL), where students run real experiments by remotely accessing true experimental apparatuses [6-7].
In this context, and in response to requests for training from local schools in Calabria (Italy), in the academic year 20/21 an RRL initiative of an innovative nature was designed and implemented, within an Italian national program (PCTO) aimed at fostering the transversal skills of high school students and at developing their specific knowledge and skills useful for adequately choosing the post-secondary training path. Since a distinctive feature of the PCTO program is to offer students

the opportunity to participate in educational activities within a real working context, the learning path was framed within the research activities of the Laboratory of Applied Physics for Cultural Heritage at the University of Calabria, with particular reference to spectroscopic and colorimetric techniques applied to the conservative diagnostic of fine arts [8]. RRLs proposed in the literature (e.g. [6-7]) are very well-designed and useful, but require a considerable technical infrastructure, including some kind of physical control interface for the apparatus in the lab, and a software user interface to remotely access the apparatus. This means that such a kind of RRL cannot be set up extemporaneously to quickly respond to specific distance learning needs, as it happened during the Covid-19 pandemic. To address these limitations, we have devised and tested a different paradigm of RRL, structured as follows: (i) students are introduced to the problem and an inquiry-oriented experimental strategy is outlined; (ii) a human instructor executes the real experiments in the laboratory, while students are participating in video streaming from home; (iii) the experimentally acquired raw data are transmitted to students, who (iv) process them and, if necessary, ask the instructor for the possible execution of subsequent measurements, which will be performed in a subsequent session in real time. Finally (v) information obtained from data processing are cooperatively discussed and conclusions are drawn. The learning activity is enriched by elements of web-mediated real time interaction, on the model of interactive lecture demonstrations [9], and all interactions among players (single students, university instructor, school tutors) are performed in video conference mode. The physics of the color, and its digital representation and processing, is the topic on which the learning path is contextualized, with particular reference to the modeling through color spaces, as the RGB model. The real experimental activities consist of various reflectance spectroscopy measurements on standard pictorial pigments, in order to investigate the relationship between perceived color and spectral shape of the reflected light. Moreover, the false-color processing method [10] has been introduced, to characterize pigments, discriminating between like-appearing colors corresponding to different spectral composition (methamerism).
In this contribution, after presenting the RRL learning path, a particular attention is devoted to the assessment-related issues. In fact, the peculiarity of this type of learning activity requires evaluation and assessment methods specifically considering the mixed real/virtual nature of lab activities and the purely virtual nature of the interaction among learners and between them and the teacher. Furthermore, given the orientation purpose covered by the learning activity, we discuss what kind of assessment (appropriate for distance learning with particular reference to RRL) is able to provide students with suitable vocational feedback, in order to help them orientate for post-secondary instruction. Attention will be paid to the evaluation of learning outcomes and to the assessment of the learning process, also in the aim of providing students with self-evaluation tools. An attempt will be made to compare the results obtained, with some works that have appeared in the literature in the meantime [1].

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How to help teachers to implement active learning strategies enhanced by formative assessment tools

Abstract. A large nunber of inquiry activities with teaching and learning materials has been developed within the national project IT Academy (2016-2022) implementing design-based research. They are designed respecting the principles of active learning, inquiry approach, digital technologies and formative assessment. The activities were trialed in the classroom in two subsequent cycles. Based on teachers´ feedback collected with the help of a questionnare the materials were modified to get the final improved version. In the paper we present the research design as well as examples of developed activities at different levels of inquiry with suggested formative assessment tools.

1 Introduction
Active learning and inquiry-based approaches place student at the centre of the learning experience. In inquiry-based science education (IBSE) students are searching for an answer to a driving question working within a specific framework similar way as scientists do. There have been large effort invested in the implementation of IBSE as well as formative assessment tools. A number of European projects has been dealing with these issues, such as ESTABLISH, FIBONACCI, CHREACT or ASSIST-ME [1-5]. They motivated project partners to continue in these efforts at national levels. In Slovakia, large national project IT Academy has been running since 2016 [6]. Its main goals emerged from the imbalance between the current goals of the curriculum emphasizing IBSE and lack of instructional materials. As a result, one of the main goals is to support education by developing teaching and learning materials based on IBSE approaches enhanced by digital technologies and formative assessment tools.

2 Methodology
In order to achieve the main project goals, design-based research has been implemented. A number of experts in the field of physics education designed teaching and learning materials respecting the agreed criteria. Each lesson has been designed at a certain level of inquiry [7] starting with a driving question respecting the 5E learning cycle model [8] and is complemented with formative assessment tools. The materials were implemented in the classroom in two subsequent cycles. In each round they were reviewed by at least five teachers. Their feedback was collected leading to the updated version. The second trialing resulted in the final version of the materials that are presented online for a wide use of teachers and students.

3 Results
In physics, 80 lesson plans for upper and 78 lesson plans for lower secondary schools have been developed with materials for teachers and students (worksheets, exemplary filled-in worksheets for teachers, computer files, and other complementary materials). The important element of the lesson plan was the use of formative assessment tools. In the following we present examples of activities grouped on the basis of the specific formative assessment tool.
a. Making predictions as a natural part of the inquiry activities
The Predict – observe – explain strategy is used almost in every activity to predict the outcomes of an experiment. Predictions are compared with the experimental results and students´ explanations are explored in order to uncover their ideas. In the activity on law of momentum conservation, students predict velocity, momentum and total momentum of carts.
b. Peer assessment in project-based learning
In this activity students in groups work on the assigned research problems. At the end they hand in the project report with detailed description of the project goals, experimental design, data collection, their analysis and interpretation and conclusions. After that each group is assigned to review two other groups´ projects for evaluation and they fill-in the evaluation report. All reports are also commented by teacher who summarize results for the whole class.
c. Self-assessment as a strategy to reflect on own student´s learning
Many activites are complemented with self-evaluation sheets that make students to think about their own learning. At the same time it provides feedback to teacher. In the activity on Faraday´s law of electromagnetic induction students investigate the voltage induced in a coil situated between the

poles of a turning horseshoe magnet. They analyze the experimental results for different parameters (frequency and number of coil turns) and reflect on the concepts and skills understanding in the self-evaluation sheet.

4 Conclusion
The experience from the implementation shows that teachers still need training in the field of IBSE and formative assessment strategies to fully understand their purpose and how to adjust teaching based on their implementation. We have designed online teacher education webinars where these issues are presented and discussed in detail.

Acknowledgements

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In the last few decades, active learning methods have been receiving more and more attention as the best approaches to developing XXI-century skills. Unlike traditional methods, which are the most effective in delivering content knowledge at low levels of Bloom's taxonomy, active learning methods support developing competencies in their holistic form, comprising content knowledge, skills, and attitudes. They transform the classroom into a student-centered environment, in which students engaged collaboratively [1], discover the world by inquiry [2], and thus create their own learning paths. However, when active learning methods replace the traditional teaching approach, standard evaluation focusing only on content knowledge becomes inadequate. The mindset for assessment needs to change from standardized tests to the assessment tools evaluating the entire learning process, also during this process. So next to the summative assessment, a lot of teacher attention should be devoted to formative assessment. Such an approach has tremendous power in learning - as found by Black and William in their meta-analysis [3], intentional use of evaluation in the classroom (formative assessment) to promote learning unequivocally improved student achievements.

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During the SAILS EU project [11], 19 science learning units in the IBL pedagogy were designed together with many ready-to-use assessment tools embedded into the material. More than 2500 teachers in 12 countries participated in SAILS teacher education programs with the IBL practical training based on the developed material. Each unit was implemented by 3-8 teachers and reported as case studies. The assessment focused on a particular set of inquiry skills and competencies in every learning unit was proposed and associated with recommended evaluation tools. Brainstorming and classroom dialogue were assessed using checkboxes (Electricity unit) and less formally (on-the-fly) in most other units. In half of the units, teachers implemented self- and peer-assessment tools for the evaluation of collaborative work. Worksheets and other student-devised material were evaluated with rubrics in almost all cases. In one-third of case studies, teachers collected their assessment data in observations.
Most of the teachers followed the units and assessment strategies proposed in the ready-to-use materials, and a few of them willingly adapted units or assessment tools to their purposes. In general, the frequency of implementation of the assessment methods spoke for teachers' preferences. A closer look (e.g., Electricity unit) into case studies revealed that some of them felt uncomfortable with the evaluation tools the others reported as favorable.
So, the conclusion is that, when designing teaching materials user-friendly and beneficial for as many classes as possible, a broad spectrum of assessment opportunities should be included, both for formative and summative evaluation of the IBL approach.

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Strategies for Active Learning and Assessment of the Learning Processes

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Abstract. Active Learning strategies are acknowledged to improve student understanding in many disciplinary fields. However, both the shift in learning objectives due to the use of these strategies and the recent need to implement active learning taking into account the requirements of mixed-mode teaching due to the COVID-19 pandemic pose the problem of developing and validating new assessment methods and techniques. In this Symposium, both examples of active learning activities focused on developing critical reasoning skills, like modelling and argumentation, and of assessment tools and methods will be presented and discussed.

1 Introduction to the Symposium
Active learning methods and strategies are credited with improving student conceptual understanding in many fields, including physics [e.g. 1-2]. This is possibly due to the strongly contextualized nature of active learning education, that emphasises on the interdependence of situation and cognition. When learning and context are put together, knowledge is seen by learners as a tool to be used dynamically to solve problems and develop critical reasoning, processes and transversal skills, rather than the final product of education.
In recent years, some innovative teaching and learning based on mixed mode real-virtual laboratories and model building, enhanced by the use of digital technologies, and aimed at actively involving students in their learning processes even remotely, has been conducted. This was further motivated by specific requests for distance learning coming from schools and universities due to the COVID-19 pandemic.
However, with the shift in teaching modes due to the pandemic and with learning objectives speficially related to active learning, focused on the development of skills and processes, the approach to assessment needs to change. New assessment techniques to review the entire learning process and determine the effectiveness of the active-learning approaches proposed to the students need to be developed and validated, [3].
The four talks part of this symposium will deal with the implementation of innovative active learning strategies, focused on hands-on and minds-on activities, on mixed-mode distance teaching, and on the activation of modelling and problem solving processes to actively engage and involve the students. The development and use of formative and summative assessment tools will also be discussed.
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Constructing a deeper meaning through modelling

Abstract. My talk will describe my work in modelling and in particular, the connection between modelling and problem solving. Key to the theory of modelling is the realization that modelling is a natural activity. We form mental models to understand a problem and the construction of a mathematical models is, in essence, an extension of this kind of natural cognitive activity. That said, modelling is not an easy skill to acquire. Modelling is best regarded as a constructivist activity in which students actively participate in the construction of meaning. It is best undertaken in groups as a form of guided enquiry.

1 Introduction
In this talk I will describe my work in modelling [1] and in particular, the connection between modelling and problem solving. A key step in teaching students how to build models is the recognition that in order to solve a problem we have to build an internal, or mental, model of the problem. This kind of modelling is a natural activity. It is a key part of reasoning and the development of a mental model of the problem leads naturally to a potential solution and the construction of mathematical model. In short, building models is, in essence, no different from the kinds of cognitive activities we undertake every day and in this presentation I will elucidate this idea.
I will argue that models are causal or explanatory mechanisms built from concepts which in turn lead to the formation of new concepts. Concepts are here regarded as embodying relationships of one kind or another. These relationships can be causal, such as the relationship between a force and acceleration, temporal, such as the relationship between change in position with time, spatial, implying the use of vectors, for example, or probabilistic. It follows that in order to build a model, students need to understand a system. They need to be able to identify objects, such as masses and charges, and understand the nature of their interactions and relationships with other elements of the system. They need to be able to recognise the various forces present as well as their consequences.
Modelling is a constructivist activity. The act of building a model not only requires the modeller to recognise and use physics knowledge, as described above, the very act of modelling is a way of actively applying knowledge and thereby deepening understanding. However, there is a good chance that students either will not have encountered all the necessary physics or, if they have, that they will not understand it sufficiently to be able to use it effectively. Therefore, it is necessary to use problems that lie within the zone of proximal development, which, as defined by Vygotsky, is that space between what they can do unaided and what they can do with guidance and prompting.
Providing guidance and prompting to ensure that students develop an effective model is thus essential to modelling as a method of active learning. It helps to ensure that students can actually build the models required to solve the problem and in so doing help them gain confidence in the process. However, as students develop at different rates and will need different amounts of guidance, it is best if models are built within groups so that students can exchange ideas and use their collective knowledge to understand the system and develop the model.
The process of building a model itself comprises three different, but not always distinct, stages. The first stage has been described above and involves developing a qualitative, mental model of the system. The second stage involves translating this understanding to a mathematical formulism and the third stage involves "running" the model and evaluating the outcome against the initial assumptions and expectations. Running the model does not mean running computer code, but developing the mathematics and solving the equations for the particular circumstances set out in the problem. Limiting cases or particular approximations might also be examined to test the validity of the model.
Modelling can thus be regarded as a process of making sense of the physical world and this connection with sensemaking is important. It is well documented that many students will approach simple problems as an exercise in finding the right equation to apply. They appear to lack an insight into the origin and meaning of the equations they seek, that they arise out of this process and reflect a physical reality. Modelling is a process by which this connection between physics and mathematics is revealed and strengthened.
The process of translating from physics to mathematics and back again is taken for granted by professional physicists and poorly understood by educators who would like to teach students how to develop this skill. I will argue in this talk that modelling is a natural way to do this. I will argue that the development of iconic, analogical, qualitative mental models is a natural process and perhaps the dominant mode of reasoning in humans. I will further argue that many concepts imply mathematical relationships and that developing a mathematical description of a physical system follows naturally from a description of the system in terms of the basic concepts.
In this talk, the whole modelling sequence, from understanding a problem, to constructing a mathematical description and assessing the outcomes of the model, will be described along with guidance on how to implement this kind of approach within a class. It will be shown that translating between representations is key to this sequence and that an effective way of assessing modelling activities is to concentrate on the use of representations and in particular, the translation from one representation to another as students pass through the different stages of modelling.

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The physics of color, and its digital modeling, explored through a real remote laboratory (RRL) learning path.

Abstract. During the pandemic, a remote learning experience based on a mixed mode real-virtual laboratory, was conducted to respond to specific requests for distance learning coming from secondary schools. The peculiarity of this type of learning activity requires evaluation and assessment methods specifically taking into account the mixed real/virtual nature of lab activities and the purely virtual nature of the interaction among learners and between them and the teacher. In this contribution, some proposals will be presented and discussed, for the evaluation of learning outcomes and the assessment of both the learning process and in the aim of providing students with self evaluation tools.

The COVID-19 pandemic crisis, by suddenly requiring a shift of learning activities in remote mode, has hardly challenged the effectiveness of distance learning methodologies [1], especially in contexts where laboratorial activities play a central role. In fact, in emergencies, virtual laboratory (VL) is a substitute for the real laboratory (RL) [2, 3], as are the real experiments made with easily available materials, self-prepared by learners at home. However, the RL remains irreplaceable, especially in didactic setups relying on investigation-based laboratorial methods [4-5]. Despite its importance, the conventional RL is sometimes not available, as for example in the case of distance learning activities. In such cases, a possible substitute could be the "real remote laboratory" (RRL), where students run real experiments by remotely accessing true experimental apparatuses [6-7].
In this context, and in response to requests for training from local schools in Calabria (Italy), in the academic year 20/21 an RRL initiative of an innovative nature was designed and implemented, within an Italian national program (PCTO) aimed at fostering the transversal skills of high school students and at developing their specific knowledge and skills useful for adequately choosing the post-secondary training path. Since a distinctive feature of the PCTO program is to offer students the opportunity to participate in educational activities within a real working context, the learning path was framed within the research activities of the Laboratory of Applied Physics for Cultural Heritage at the University of Calabria, with particular reference to spectroscopic and colorimetric techniques applied to the conservative diagnostic of fine arts [8]. RRLs proposed in the literature (e.g. [6-7]) are very well-designed and useful, but require a considerable technical infrastructure, including some kind of physical control interface for the apparatus in the lab, and a software user interface to remotely access the apparatus. This means that such a kind of RRL cannot be set up extemporaneously to quickly respond to specific distance learning needs, as it happened during the Covid-19 pandemic. To address these limitations, we have devised and tested a different paradigm of RRL, structured as follows: (i) students are introduced to the problem and an inquiry-oriented experimental strategy is outlined; (ii) a human instructor executes the real experiments in the laboratory, while students are participating in video streaming from home; (iii) the experimentally acquired raw data are transmitted to students, who (iv) process them and, if necessary, ask the instructor for the possible execution of subsequent measurements, which will be performed in a subsequent session in real time. Finally (v) information obtained from data processing are cooperatively discussed and conclusions are drawn. The learning activity is enriched by elements of web-mediated real time interaction, on the model of interactive lecture demonstrations [9], and all interactions among players (single students, university instructor, school tutors) are performed in video conference mode. The physics of the color, and its digital representation and processing, is the topic on which the learning path is contextualized, with particular reference to the modeling through color spaces, as the RGB model. The real experimental activities consist of various reflectance spectroscopy measurements on standard pictorial pigments, in order to investigate the relationship between perceived color and spectral shape of the reflected light. Moreover, the false-color processing method [10] has been introduced, to characterize pigments, discriminating between like-appearing colors corresponding to different spectral composition (methamerism).
In this contribution, after presenting the RRL learning path, a particular attention is devoted to the assessment-related issues. In fact, the peculiarity of this type of learning activity requires evaluation and assessment methods specifically considering the mixed real/virtual nature of lab activities and the purely virtual nature of the interaction among learners and between them and the teacher. Furthermore, given the orientation purpose covered by the learning activity, we discuss what kind of assessment (appropriate for distance learning with particular reference to RRL) is able to provide

students with suitable vocational feedback, in order to help them orientate for post-secondary instruction. Attention will be paid to the evaluation of learning outcomes and to the assessment of the learning process, also in the aim of providing students with self-evaluation tools. An attempt will be made to compare the results obtained, with some works that have appeared in the literature in the meantime [1].

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How to help teachers to implement active learning strategies enhanced by formative assessment tools

Abstract. A large nunber of inquiry activities with teaching and learning materials has been developed within the national project IT Academy (2016-2022) implementing design-based research. They are designed respecting the principles of active learning, inquiry approach, digital technologies and formative assessment. The activities were trialed in the classroom in two subsequent cycles. Based on teachers´ feedback collected with the help of a questionnare the materials were modified to get the final improved version. In the paper we present the research design as well as examples of developed activities at different levels of inquiry with suggested formative assessment tools.

1 Introduction
Active learning and inquiry-based approaches place student at the centre of the learning experience. In inquiry-based science education (IBSE) students are searching for an answer to a driving question working within a specific framework similar way as scientists do. There have been large effort invested in the implementation of IBSE as well as formative assessment tools. A number of European projects has been dealing with these issues, such as ESTABLISH, FIBONACCI, CHREACT or ASSIST-ME [1-5]. They motivated project partners to continue in these efforts at national levels. In Slovakia, large national project IT Academy has been running since 2016 [6]. Its main goals emerged from the imbalance between the current goals of the curriculum emphasizing IBSE and lack of instructional materials. As a result, one of the main goals is to support education by developing teaching and learning materials based on IBSE approaches enhanced by digital technologies and formative assessment tools.

2 Methodology
In order to achieve the main project goals, design-based research has been implemented. A number

of experts in the field of physics education designed teaching and learning materials respecting the agreed criteria. Each lesson has been designed at a certain level of inquiry [7] starting with a driving question respecting the 5E learning cycle model [8] and is complemented with formative assessment tools. The materials were implemented in the classroom in two subsequent cycles. In each round they were reviewed by at least five teachers. Their feedback was collected leading to the updated version. The second trialing resulted in the final version of the materials that are presented online for a wide use of teachers and students.

3 Results

In physics, 80 lesson plans for upper and 78 lesson plans for lower secondary schools have been developed with materials for teachers and students (worksheets, exemplary filled-in worksheets for teachers, computer files, and other complementary materials). The important element of the lesson plan was the use of formative assessment tools. In the following we present examples of activities grouped on the basis of the specific formative assessment tool.

a. Making predictions as a natural part of the inquiry activities

The Predict – observe – explain strategy is used almost in every activity to predict the outcomes of an experiment. Predictions are compared with the experimental results and students´ explanations are explored in order to uncover their ideas. In the activity on law of momentum conservation, students predict velocity, momentum and total momentum of carts.

b. Peer assessment in project-based learning

In this activity students in groups work on the assigned research problems. At the end they hand in the project report with detailed description of the project goals, experimental design, data collection, their analysis and interpretation and conclusions. After that each group is assigned to review two other groups´ projects for evaluation and they fill-in the evaluation report. All reports are also commented by teacher who summarize results for the whole class.

c. Self-assessment as a strategy to reflect on own student´s learning

Many activites are complemented with self-evaluation sheets that make students to think about their own learning. At the same time it provides feedback to teacher. In the activity on Faraday´s law of electromagnetic induction students investigate the voltage induced in a coil situated between the poles of a turning horseshoe magnet. They analyze the experimental results for different parameters (frequency and number of coil turns) and reflect on the concepts and skills understanding in the self-evaluation sheet.

4 Conclusion

The experience from the implementation shows that teachers still need training in the field of IBSE and formative assessment strategies to fully understand their purpose and how to adjust teaching based on their implementation. We have designed online teacher education webinars where these issues are presented and discussed in detail.

Acknowledgements

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Strategies for Assessment of Inquiry Learning in Science

Abstract. Active learning methods receiving more and more attention require a design of assessment methods tailored to their goals and evaluation of the entire learning process. In the SAILS project, 19 science learning units in the inquiry-based learning approach were designed together with the whole spectrum of assessment tools. Each unit was tested in 3-8 classes, and the teachers reported their experiences in case studies. Teachers proved to be able to conduct the IBL lessons and use the assessment tools designed for formative assessment, however, their preferences for evaluation differed.

1 Introduction
In the last few decades, active learning methods have been receiving more and more attention as the best approaches to developing XXI-century skills. Unlike traditional methods, which are the most effective in delivering content knowledge at low levels of Bloom's taxonomy, active learning methods support developing competencies in their holistic form, comprising content knowledge, skills, and attitudes. They transform the classroom into a student-centered environment, in which students engaged collaboratively [1], discover the world by inquiry [2], and thus create their own learning paths. However, when active learning methods replace the traditional teaching approach, standard evaluation focusing only on content knowledge becomes inadequate. The mindset for assessment needs to change from standardized tests to the assessment tools evaluating the entire learning process, also during this process. So next to the summative assessment, a lot of teacher attention should be devoted to formative assessment. Such an approach has tremendous power in learning - as found by Black and William in their meta-analysis [3], intentional use of evaluation in the classroom (formative assessment) to promote learning unequivocally improved student achievements.

2 Inquiry-based learning and assessment
Inquiry-based learning (IBL) has been one of the most advocated active learning methods in science education over the last two decades is [4]. It leads to knowledge and understanding of the world by asking inquiry questions, formulating hypotheses, and testing them by collecting data during scientific experiments and using them as evidence to explain phenomena or events. In general, learning by inquiry follows a research cycle the researchers employ when they study a scientific problem. The concept of this pedagogy is not new; however, its educational potential has been increasing in technology-based societies [2]. It has been associated with increased students' motivation and interest in science, supporting the development of inquiry competencies and conceptual understanding [5].
As in any other learning environments and teaching/learning strategies, assessment in the IBL involves a collection of data, its analysis, formulation of conclusions and a feedback given to the students. Formative assessment (also called 'assessment for learning' [6]) serves the improvement of the learning process and is linked to the instant feedback given to students during this process. It can become relatively informal through on-the-fly interactions (informal formative assessment conversations [7]) or can be implemented more formally – with the help of evaluation tools and assessment plans prepared in advance (e.g., rubrics [8]). However, if used in the IBL approach, it should also reflect the goals and nature of this pedagogy [9-10].

3 Research and results
During the SAILS EU project [11], 19 science learning units in the IBL pedagogy were designed together with many ready-to-use assessment tools embedded into the material. More than 2500 teachers in 12 countries participated in SAILS teacher education programs with the IBL practical training based on the developed material. Each unit was implemented by 3-8 teachers and reported as case studies. The assessment focused on a particular set of inquiry skills and competencies in every learning unit was proposed and associated with recommended evaluation tools. Brainstorming and classroom dialogue were assessed using checkboxes (Electricity unit) and less formally (on-the-fly) in most other units. In half of the units, teachers implemented self- and peer-assessment tools for the evaluation of collaborative work. Worksheets and other student-devised material were evaluated with rubrics in almost all cases. In one-third of case studies, teachers collected their assessment data in observations.
Most of the teachers followed the units and assessment strategies proposed in the ready-to-use materials, and a few of them willingly adapted units or assessment tools to their purposes. In general, the frequency of implementation of the assessment methods spoke for teachers' preferences. A closer look (e.g., Electricity unit) into case studies revealed that some of them felt uncomfortable with the evaluation tools the others reported as favorable.
So, the conclusion is that, when designing teaching materials user-friendly and beneficial for as many classes as possible, a broad spectrum of assessment opportunities should be included, both for formative and summative evaluation of the IBL approach.

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Abstract. Active Learning strategies are acknowledged to improve student understanding in many disciplinary fields. However, both the shift in learning objectives due to the use of these strategies and the recent need to implement active learning taking into account the requirements of mixed-mode teaching due to the COVID-19 pandemic pose the problem of developing and validating new assessment methods and techniques. In this Symposium, both examples of active learning activities focused on developing critical reasoning skills, like modelling and argumentation, and of assessment tools and methods will be presented and discussed.

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However, with the shift in teaching modes due to the pandemic and with learning objectives spefically related to active learning, focused on the development of skills and processes, the approach to assessment needs to change. New assessment techniques to review the entire learning process and determine the effectiveness of the active-learning approaches proposed to the students need to be developed and validated, [3].
The four talks part of this symposium will deal with the implementation of innovative active learning strategies, focused on hands-on and minds-on activities, on mixed-mode distance teaching, and on the activation of modelling and problem solving processes to actively engage and involve the students. The development and use of formative and summative assessment tools will also be discussed.
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Constructing a deeper meaning through modelling

Abstract. My talk will describe my work in modelling and in particular, the connection between modelling and problem solving. Key to the theory of modelling is the realization that modelling is a natural activity. We form mental models to understand a problem and the construction of a mathematical models is, in essence, an extension of this kind of natural cognitive activity. That said, modelling is not an easy skill to acquire. Modelling is best regarded as a constructivist activity in which students actively participate in the construction of meaning. It is best undertaken in groups as a form of guided enquiry.

1 Introduction
In this talk I will describe my work in modelling [1] and in particular, the connection between modelling and problem solving. A key step in teaching students how to build models is the recognition that in order to solve a problem we have to build an internal, or mental, model of the problem. This kind of modelling is a natural activity. It is a key part of reasoning and the development of a mental model of the problem leads naturally to a potential solution and the construction of mathematical model. In short, building models is, in essence, no different from the kinds of cognitive activities we undertake every day and in this presentation I will elucidate this idea.
I will argue that models are causal or explanatory mechanisms built from concepts which in turn lead to the formation of new concepts. Concepts are here regarded as embodying relationships of one kind or another. These relationships can be causal, such as the relationship between a force and acceleration, temporal, such as the relationship between change in position with time, spatial, implying the use of vectors, for example, or probabilistic. It follows that in order to build a model, students need to understand a system. They need to be able to identify objects, such as masses and charges, and understand the nature of their interactions and relationships with other elements of the system. They need to be able to recognise the various forces present as well as their consequences.
Modelling is a constructivist activity. The act of building a model not only requires the modeller to recognise and use physics knowledge, as described above, the very act of modelling is a way of actively applying knowledge and thereby deepening understanding. However, there is a good chance that students either will not have encountered all the necessary physics or, if they have, that they will not understand it sufficiently to be able to use it effectively. Therefore, it is necessary to use problems that lie within the zone of proximal development, which, as defined by Vygotsky, is that space between what they can do unaided and what they can do with guidance and prompting. Providing guidance and prompting to ensure that students develop an effective model is thus essential to modelling as a method of active learning. It helps to ensure that students can actually build the models required to solve the problem and in so doing help them gain confidence in the process. However, as students develop at different rates and will need different amounts of guidance, it is best if models are built within groups so that students can exchange ideas and use their collective knowledge to understand the system and develop the model.

The process of building a model itself comprises three different, but not always distinct, stages. The first stage has been described above and involves developing a qualitative, mental model of the system. The second stage involves translating this understanding to a mathematical formulism and the third stage involves "running" the model and evaluating the outcome against the initial assumptions and expectations. Running the model does not mean running computer code, but developing the mathematics and solving the equations for the particular circumstances set out in the problem. Limiting cases or particular approximations might also be examined to test the validity of the model. Modelling can thus be regarded as a process of making sense of the physical world and this connection with sensemaking is important. It is well documented that many students will approach simple problems as an exercise in finding the right equation to apply. They appear to lack an insight into the origin and meaning of the equations they seek, that they arise out of this process and reflect a physical reality. Modelling is a process by which this connection between physics and mathematics is revealed and strengthened.

The process of translating from physics to mathematics and back again is taken for granted by professional physicists and poorly understood by educators who would like to teach students how to develop this skill. I will argue in this talk that modelling is a natural way to do this. I will argue that the development of iconic, analogical, qualitative mental models is a natural process and perhaps the dominant mode of reasoning in humans. I will further argue that many concepts imply mathematical relationships and that developing a mathematical description of a physical system follows naturally from a description of the system in terms of the basic concepts.

In this talk, the whole modelling sequence, from understanding a problem, to constructing a mathematical description and assessing the outcomes of the model, will be described along with guidance on how to implement this kind of approach within a class. It will be shown that translating between representations is key to this sequence and that an effective way of assessing modelling activities is to concentrate on the use of representations and in particular, the translation from one representation to another as students pass through the different stages of modelling.

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The physics of color, and its digital modeling, explored through a real remote laboratory (RRL) learning path.

Abstract. During the pandemic, a remote learning experience based on a mixed mode real-virtual laboratory, was conducted to respond to specific requests for distance learning coming from secondary schools. The peculiarity of this type of learning activity requires evaluation and assessment methods specifically taking into account the mixed real/virtual nature of lab activities and the purely virtual nature of the interaction among learners and between them and the teacher. In this contribution, some proposals will be presented and discussed, for the evaluation of learning outcomes and the assessment of both the learning process and in the aim of providing students with self evaluation tools.

The COVID-19 pandemic crisis, by suddenly requiring a shift of learning activities in remote mode, has hardly challenged the effectiveness of distance learning methodologies [1], especially in contexts where laboratorial activities play a central role. In fact, in emergencies, virtual laboratory (VL) is a substitute for the real laboratory (RL) [2, 3], as are the real experiments made with easily available materials, self-prepared by learners at home. However, the RL remains irreplaceable, especially in didactic setups relying on investigation-based laboratorial methods [4-5]. Despite its importance, the conventional RL is sometimes not available, as for example in the case of distance learning activities. In such cases, a possible substitute could be the "real remote laboratory" (RRL), where students run real experiments by remotely accessing true experimental apparatuses [6-7].

In this context, and in response to requests for training from local schools in Calabria (Italy), in the academic year 20/21 an RRL initiative of an innovative nature was designed and implemented, within an Italian national program (PCTO) aimed at fostering the transversal skills of high school students and at developing their specific knowledge and skills useful for adequately choosing the post-secondary training path. Since a distinctive feature of the PCTO program is to offer students the opportunity to participate in educational activities within a real working context, the learning path was framed within the research activities of the Laboratory of Applied Physics for Cultural Heritage at the University of Calabria, with particular reference to spectroscopic and colorimetric

techniques applied to the conservative diagnostic of fine arts [8]. RRLs proposed in the literature (e.g. [6-7]) are very well-designed and useful, but require a considerable technical infrastructure, including some kind of physical control interface for the apparatus in the lab, and a software user interface to remotely access the apparatus. This means that such a kind of RRL cannot be set up extemporaneously to quickly respond to specific distance learning needs, as it happened during the Covid-19 pandemic. To address these limitations, we have devised and tested a different paradigm of RRL, structured as follows: (i) students are introduced to the problem and an inquiry-oriented experimental strategy is outlined; (ii) a human instructor executes the real experiments in the laboratory, while students are participating in video streaming from home; (iii) the experimentally acquired raw data are transmitted to students, who (iv) process them and, if necessary, ask the instructor for the possible execution of subsequent measurements, which will be performed in a subsequent session in real time. Finally (v) information obtained from data processing are cooperatively discussed and conclusions are drawn. The learning activity is enriched by elements of web-mediated real time interaction, on the model of interactive lecture demonstrations [9], and all interactions among players (single students, university instructor, school tutors) are performed in video conference mode. The physics of the color, and its digital representation and processing, is the topic on which the learning path is contextualized, with particular reference to the modeling through color spaces, as the RGB model. The real experimental activities consist of various reflectance spectroscopy measurements on standard pictorial pigments, in order to investigate the relationship between perceived color and spectral shape of the reflected light. Moreover, the false-color processing method [10] has been introduced, to characterize pigments, discriminating between like-appearing colors corresponding to different spectral composition (methamerism).
In this contribution, after presenting the RRL learning path, a particular attention is devoted to the assessment-related issues. In fact, the peculiarity of this type of learning activity requires evaluation and assessment methods specifically considering the mixed real/virtual nature of lab activities and the purely virtual nature of the interaction among learners and between them and the teacher. Furthermore, given the orientation purpose covered by the learning activity, we discuss what kind of assessment (appropriate for distance learning with particular reference to RRL) is able to provide students with suitable vocational feedback, in order to help them orientate for post-secondary instruction. Attention will be paid to the evaluation of learning outcomes and to the assessment of the learning process, also in the aim of providing students with self-evaluation tools. An attempt will be made to compare the results obtained, with some works that have appeared in the literature in the meantime [1].

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How to help teachers to implement active learning strategies enhanced by formative assessment tools

Abstract. A large nunber of inquiry activities with teaching and learning materials has been developed within the national project IT Academy (2016-2022) implementing design-based research. They are designed respecting the principles of active learning, inquiry approach, digital technologies and formative assessment. The activities were trialed in the classroom in two subsequent cycles. Based on teachers´ feedback collected with the help of a questionnare the materials were modified to get the final improved version. In the paper we present the research design as well as examples of developed activities at different levels of inquiry with suggested formative assessment tools.

1 Introduction
Active learning and inquiry-based approaches place student at the centre of the learning experience. In inquiry-based science education (IBSE) students are searching for an answer to a driving question working within a specific framework similar way as scientists do. There have been large effort invested in the implementation of IBSE as well as formative assessment tools. A number of European projects has been dealing with these issues, such as ESTABLISH, FIBONACCI, CHREACT or ASSIST-ME [1-5]. They motivated project partners to continue in these efforts at national levels. In Slovakia, large national project IT Academy has been running since 2016 [6]. Its main goals emerged from the imbalance between the current goals of the curriculum emphasizing IBSE and lack of instructional materials. As a result, one of the main goals is to support education by developing teaching and learning materials based on IBSE approaches enhanced by digital technologies and formative assessment tools.

2 Methodology
In order to achieve the main project goals, design-based research has been implemented. A number of experts in the field of physics education designed teaching and learning materials respecting the agreed criteria. Each lesson has been designed at a certain level of inquiry [7] starting with a driving question respecting the 5E learning cycle model [8] and is complemented with formative assessment tools. The materials were implemented in the classroom in two subsequent cycles. In each round they were reviewed by at least five teachers. Their feedback was collected leading to the updated version. The second trialing resulted in the final version of the materials that are presented online for a wide use of teachers and students.

3 Results
In physics, 80 lesson plans for upper and 78 lesson plans for lower secondary schools have been developed with materials for teachers and students (worksheets, exemplary filled-in worksheets for teachers, computer files, and other complementary materials). The important element of the lesson plan was the use of formative assessment tools. In the following we present examples of activities grouped on the basis of the specific formative assessment tool.
a. Making predictions as a natural part of the inquiry activities
The Predict – observe – explain strategy is used almost in every activity to predict the outcomes of an experiment. Predictions are compared with the experimental results and students´ explanations are explored in order to uncover their ideas. In the activity on law of momentum conservation, students predict velocity, momentum and total momentum of carts.
b. Peer assessment in project-based learning
In this activity students in groups work on the assigned research problems. At the end they hand in the project report with detailed description of the project goals, experimental design, data collection, their analysis and interpretation and conclusions. After that each group is assigned to review two other groups´ projects for evaluation and they fill-in the evaluation report. All reports are also commented by teacher who summarize results for the whole class.
c. Self-assessment as a strategy to reflect on own student´s learning
Many activites are complemented with self-evaluation sheets that make students to think about their own learning. At the same time it provides feedback to teacher. In the activity on Faraday´s law of electromagnetic induction students investigate the voltage induced in a coil situated between the poles of a turning horseshoe magnet. They analyze the experimental results for different parameters (frequency and number of coil turns) and reflect on the concepts and skills understanding in the self-evaluation sheet.

4 Conclusion
The experience from the implementation shows that teachers still need training in the field of IBSE and formative assessment strategies to fully understand their purpose and how to adjust teaching based on their implementation. We have designed online teacher education webinars where these issues are presented and discussed in detail.

Acknowledgements

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Strategies for Assessment of Inquiry Learning in Science

Abstract. Active learning methods receiving more and more attention require a design of assessment methods tailored to their goals and evaluation of the entire learning process. In the SAILS project, 19 science learning units in the inquiry-based learning approach were designed together with the whole spectrum of assessment tools. Each unit was tested in 3-8 classes, and the teachers reported their experiences in case studies. Teachers proved to be able to conduct the IBL lessons and use the assessment tools designed for formative assessment, however, their preferences for evaluation differed.

1 Introduction
In the last few decades, active learning methods have been receiving more and more attention as the best approaches to developing XXI-century skills. Unlike traditional methods, which are the most effective in delivering content knowledge at low levels of Bloom's taxonomy, active learning methods support developing competencies in their holistic form, comprising content knowledge, skills, and attitudes. They transform the classroom into a student-centered environment, in which students engaged collaboratively [1], discover the world by inquiry [2], and thus create their own learning paths. However, when active learning methods replace the traditional teaching approach, standard evaluation focusing only on content knowledge becomes inadequate. The mindset for assessment needs to change from standardized tests to the assessment tools evaluating the entire learning process, also during this process. So next to the summative assessment, a lot of teacher attention should be devoted to formative assessment. Such an approach has tremendous power in learning - as found by Black and William in their meta-analysis [3], intentional use of evaluation in the classroom (formative assessment) to promote learning unequivocally improved student achievements.

2 Inquiry-based learning and assessment
Inquiry-based learning (IBL) has been one of the most advocated active learning methods in science education over the last two decades is [4]. It leads to knowledge and understanding of the world by asking inquiry questions, formulating hypotheses, and testing them by collecting data during scientific experiments and using them as evidence to explain phenomena or events. In general, learning by inquiry follows a research cycle the researchers employ when they study a scientific problem. The concept of this pedagogy is not new; however, its educational potential has been increasing in technology-based societies [2]. It has been associated with increased students' motivation and interest in science, supporting the development of inquiry competencies and conceptual understanding [5].
As in any other learning environments and teaching/learning strategies, assessment in the IBL involves a collection of data, its analysis, formulation of conclusions and a feedback given to the students. Formative assessment (also called 'assessment for learning' [6]) serves the improvement of

the learning process and is linked to the instant feedback given to students during this process. It can become relatively informal through on-the-fly interactions (informal formative assessment conversations [7]) or can be implemented more formally – with the help of evaluation tools and assessment plans prepared in advance (e.g., rubrics [8]). However, if used in the IBL approach, it should also reflect the goals and nature of this pedagogy [9-10].

3 Research and results
During the SAILS EU project [11], 19 science learning units in the IBL pedagogy were designed together with many ready-to-use assessment tools embedded into the material. More than 2500 teachers in 12 countries participated in SAILS teacher education programs with the IBL practical training based on the developed material. Each unit was implemented by 3-8 teachers and reported as case studies. The assessment focused on a particular set of inquiry skills and competencies in every learning unit was proposed and associated with recommended evaluation tools. Brainstorming and classroom dialogue were assessed using checkboxes (Electricity unit) and less formally (on-the-fly) in most other units. In half of the units, teachers implemented self- and peer-assessment tools for the evaluation of collaborative work. Worksheets and other student-devised material were evaluated with rubrics in almost all cases. In one-third of case studies, teachers collected their assessment data in observations.
Most of the teachers followed the units and assessment strategies proposed in the ready-to-use materials, and a few of them willingly adapted units or assessment tools to their purposes. In general, the frequency of implementation of the assessment methods spoke for teachers' preferences. A closer look (e.g., Electricity unit) into case studies revealed that some of them felt uncomfortable with the evaluation tools the others reported as favorable.
So, the conclusion is that, when designing teaching materials user-friendly and beneficial for as many classes as possible, a broad spectrum of assessment opportunities should be included, both for formative and summative evaluation of the IBL approach.

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Strategies for Active Learning and Assessment of the Learning Processes

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Abstract. Active Learning strategies are acknowledged to improve student understanding in many disciplinary fields. However, both the shift in learning objectives due to the use of these strategies and the recent need to implement active learning taking into account the requirements of mixed-mode teaching due to the COVID-19 pandemic pose the problem of developing and validating new assessment methods and techniques. In this Symposium, both examples of active learning activities focused on developing critical reasoning skills, like modelling and argumentation, and of assessment tools and methods will be presented and discussed.

1 Introduction to the Symposium
Active learning methods and strategies are credited with improving student conceptual understanding in many fields, including physics [e.g. 1-2]. This is possibly due to the strongly contextualized nature of active learning education, that emphasises on the interdependence of situation and cognition. When learning and context are put together, knowledge is seen by learners as a tool to be used dynamically to solve problems and develop critical reasoning, processes and transversal skills, rather than the final product of education.
In recent years, some innovative teaching and learning based on mixed mode real-virtual laboratories and model building, enhanced by the use of digital technologies, and aimed at actively involving students in their learning processes even remotely, has been conducted. This was further motivated by specific requests for distance learning coming from schools and universities due to the COVID-19 pandemic.
However, with the shift in teaching modes due to the pandemic and with learning objectives spefically related to active learning, focused on the development of skills and processes, the approach to assessment needs to change. New assessment techniques to review the entire learning process and determine the effectiveness of the active-learning approaches proposed to the students need to be developed and validated, [3].
The four talks part of this symposium will deal with the implementation of innovative active learning strategies, focused on hands-on and minds-on activities, on mixed-mode distance teaching, and on the activation of modelling and problem solving processes to actively engage and involve the students. The development and use of formative and summative assessment tools will also be discussed.
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Constructing a deeper meaning through modelling

Abstract. My talk will describe my work in modelling and in particular, the connection between modelling and problem solving. Key to the theory of modelling is the realization that modelling is a natural activity. We form mental models to understand a problem and the construction of a mathematical models is, in essence, an extension of this kind of natural cognitive activity. That said, modelling is not an easy skill to acquire. Modelling is best regarded as a constructivist activity in which students actively participate in the construction of meaning. It is best undertaken in groups as a form of guided enquiry.

1 Introduction

In this talk I will describe my work in modelling [1] and in particular, the connection between modelling and problem solving. A key step in teaching students how to build models is the recognition that in order to solve a problem we have to build an internal, or mental, model of the problem. This kind of modelling is a natural activity. It is a key part of reasoning and the development of a mental model of the problem leads naturally to a potential solution and the construction of mathematical model. In short, building models is, in essence, no different from the kinds of cognitive activities we undertake every day and in this presentation I will elucidate this idea.

I will argue that models are causal or explanatory mechanisms built from concepts which in turn lead to the formation of new concepts. Concepts are here regarded as embodying relationships of one kind or another. These relationships can be causal, such as the relationship between a force and acceleration, temporal, such as the relationship between change in position with time, spatial, implying the use of vectors, for example, or probabilistic. It follows that in order to build a model, students need to understand a system. They need to be able to identify objects, such as masses and charges, and understand the nature of their interactions and relationships with other elements of the system. They need to be able to recognise the various forces present as well as their consequences.

Modelling is a constructivist activity. The act of building a model not only requires the modeller to recognise and use physics knowledge, as described above, the very act of modelling is a way of actively applying knowledge and thereby deepening understanding. However, there is a good chance that students either will not have encountered all the necessary physics or, if they have, that they will not understand it sufficiently to be able to use it effectively. Therefore, it is necessary to use problems that lie within the zone of proximal development, which, as defined by Vygotsky, is that space between what they can do unaided and what they can do with guidance and prompting.

Providing guidance and prompting to ensure that students develop an effective model is thus essential to modelling as a method of active learning. It helps to ensure that students can actually build the models required to solve the problem and in so doing help them gain confidence in the process. However, as students develop at different rates and will need different amounts of guidance, it is best if models are built within groups so that students can exchange ideas and use their collective knowledge to understand the system and develop the model.

The process of building a model itself comprises three different, but not always distinct, stages. The first stage has been described above and involves developing a qualitative, mental model of the system. The second stage involves translating this understanding to a mathematical formulism and the third stage involves "running" the model and evaluating the outcome against the initial assumptions and expectations. Running the model does not mean running computer code, but developing the mathematics and solving the equations for the particular circumstances set out in the problem. Limiting cases or particular approximations might also be examined to test the validity of the model.

Modelling can thus be regarded as a process of making sense of the physical world and this connection with sensemaking is important. It is well documented that many students will approach simple problems as an exercise in finding the right equation to apply. They appear to lack an insight into the origin and meaning of the equations they seek, that they arise out of this process and reflect a physical reality. Modelling is a process by which this connection between physics and mathematics is revealed and strengthened.

The process of translating from physics to mathematics and back again is taken for granted by professional physicists and poorly understood by educators who would like to teach students how to develop this skill. I will argue in this talk that modelling is a natural way to do this. I will argue that the development of iconic, analogical, qualitative mental models is a natural process and perhaps the dominant mode of reasoning in humans. I will further argue that many concepts imply mathematical relationships and that developing a mathematical description of a physical system follows naturally from a description of the system in terms of the basic concepts.

In this talk, the whole modelling sequence, from understanding a problem, to constructing a mathematical description and assessing the outcomes of the model, will be described along with guidance on how to implement this kind of approach within a class. It will be shown that translating between representations is key to this sequence and that an effective way of assessing modelling activities is to concentrate on the use of representations and in particular, the translation from one representation to another as students pass through the different stages of modelling.

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The physics of color, and its digital modeling, explored through a real remote laboratory (RRL) learning path.

Abstract. During the pandemic, a remote learning experience based on a mixed mode real-virtual laboratory, was conducted to respond to specific requests for distance learning coming from secondary schools. The peculiarity of this type of learning activity requires evaluation and assessment methods specifically taking into account the mixed real/virtual nature of lab activities and the purely virtual nature of the interaction among learners and between them and the teacher. In this contribution, some proposals will be presented and discussed, for the evaluation of learning outcomes and the assessment of both the learning process and in the aim of providing students with self evaluation tools.

The COVID-19 pandemic crisis, by suddenly requiring a shift of learning activities in remote mode, has hardly challenged the effectiveness of distance learning methodologies [1], especially in contexts where laboratorial activities play a central role. In fact, in emergencies, virtual laboratory (VL) is a substitute for the real laboratory (RL) [2, 3], as are the real experiments made with easily available materials, self-prepared by learners at home. However, the RL remains irreplaceable, especially in didactic setups relying on investigation-based laboratorial methods [4-5]. Despite its importance, the conventional RL is sometimes not available, as for example in the case of distance learning activities. In such cases, a possible substitute could be the "real remote laboratory" (RRL), where students run real experiments by remotely accessing true experimental apparatuses [6-7].
In this context, and in response to requests for training from local schools in Calabria (Italy), in the academic year 20/21 an RRL initiative of an innovative nature was designed and implemented, within an Italian national program (PCTO) aimed at fostering the transversal skills of high school students and at developing their specific knowledge and skills useful for adequately choosing the post-secondary training path. Since a distinctive feature of the PCTO program is to offer students the opportunity to participate in educational activities within a real working context, the learning path was framed within the research activities of the Laboratory of Applied Physics for Cultural Heritage at the University of Calabria, with particular reference to spectroscopic and colorimetric techniques applied to the conservative diagnostic of fine arts [8]. RRLs proposed in the literature (e.g. [6-7]) are very well-designed and useful, but require a considerable technical infrastructure, including some kind of physical control interface for the apparatus in the lab, and a software user interface to remotely access the apparatus. This means that such a kind of RRL cannot be set up extemporaneously to quickly respond to specific distance learning needs, as it happened during the Covid-19 pandemic. To address these limitations, we have devised and tested a different paradigm of RRL, structured as follows: (i) students are introduced to the problem and an inquiry-oriented experimental strategy is outlined; (ii) a human instructor executes the real experiments in the laboratory, while students are participating in video streaming from home; (iii) the experimentally acquired raw data are transmitted to students, who (iv) process them and, if necessary, ask the instructor for the possible execution of subsequent measurements, which will be performed in a subsequent session in real time. Finally (v) information obtained from data processing are cooperatively discussed and conclusions are drawn. The learning activity is enriched by elements of web-mediated real time interaction, on the model of interactive lecture demonstrations [9], and all interactions among players (single students, university instructor, school tutors) are performed in video conference mode. The physics of the color, and its digital representation and processing, is the topic on which the learning path is contextualized, with particular reference to the modeling through color spaces, as the RGB model. The real experimental activities consist of various reflectance spectroscopy measurements on standard pictorial pigments, in order to investigate the relationship between perceived color and spectral shape of the reflected light. Moreover, the false-color processing method [10] has been introduced, to characterize pigments, discriminating between like-appearing colors corresponding to different spectral composition (methamerism).
In this contribution, after presenting the RRL learning path, a particular attention is devoted to the assessment-related issues. In fact, the peculiarity of this type of learning activity requires evaluation and assessment methods specifically considering the mixed real/virtual nature of lab activities and the purely virtual nature of the interaction among learners and between them and the teacher. Furthermore, given the orientation purpose covered by the learning activity, we discuss what kind of assessment (appropriate for distance learning with particular reference to RRL) is able to provide students with suitable vocational feedback, in order to help them orientate for post-secondary instruction. Attention will be paid to the evaluation of learning outcomes and to the assessment of the learning process, also in the aim of providing students with self-evaluation tools. An attempt will

be made to compare the results obtained, with some works that have appeared in the literature in the meantime [1].

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How to help teachers to implement active learning strategies enhanced by formative assessment tools

Abstract. A large nunber of inquiry activities with teaching and learning materials has been developed within the national project IT Academy (2016-2022) implementing design-based research. They are designed respecting the principles of active learning, inquiry approach, digital technologies and formative assessment. The activities were trialed in the classroom in two subsequent cycles. Based on teachers´ feedback collected with the help of a questionnare the materials were modified to get the final improved version. In the paper we present the research design as well as examples of developed activities at different levels of inquiry with suggested formative assessment tools.

1 Introduction
Active learning and inquiry-based approaches place student at the centre of the learning experience. In inquiry-based science education (IBSE) students are searching for an answer to a driving question working within a specific framework similar way as scientists do. There have been large effort invested in the implementation of IBSE as well as formative assessment tools. A number of European projects has been dealing with these issues, such as ESTABLISH, FIBONACCI, CHREACT or ASSIST-ME [1-5]. They motivated project partners to continue in these efforts at national levels. In Slovakia, large national project IT Academy has been running since 2016 [6]. Its main goals emerged from the imbalance between the current goals of the curriculum emphasizing IBSE and lack of instructional materials. As a result, one of the main goals is to support education by developing teaching and learning materials based on IBSE approaches enhanced by digital technologies and formative assessment tools.

2 Methodology
In order to achieve the main project goals, design-based research has been implemented. A number of experts in the field of physics education designed teaching and learning materials respecting the agreed criteria. Each lesson has been designed at a certain level of inquiry [7] starting with a driving question respecting the 5E learning cycle model [8] and is complemented with formative assessment

tools. The materials were implemented in the classroom in two subsequent cycles. In each round they were reviewed by at least five teachers. Their feedback was collected leading to the updated version. The second trialing resulted in the final version of the materials that are presented online for a wide use of teachers and students.

3 Results
In physics, 80 lesson plans for upper and 78 lesson plans for lower secondary schools have been developed with materials for teachers and students (worksheets, exemplary filled-in worksheets for teachers, computer files, and other complementary materials). The important element of the lesson plan was the use of formative assessment tools. In the following we present examples of activities grouped on the basis of the specific formative assessment tool.
a. Making predictions as a natural part of the inquiry activities
The Predict – observe – explain strategy is used almost in every activity to predict the outcomes of an experiment. Predictions are compared with the experimental results and students´ explanations are explored in order to uncover their ideas. In the activity on law of momentum conservation, students predict velocity, momentum and total momentum of carts.
b. Peer assessment in project-based learning
In this activity students in groups work on the assigned research problems. At the end they hand in the project report with detailed description of the project goals, experimental design, data collection, their analysis and interpretation and conclusions. After that each group is assigned to review two other groups´ projects for evaluation and they fill-in the evaluation report. All reports are also commented by teacher who summarize results for the whole class.
c. Self-assessment as a strategy to reflect on own student´s learning
Many activites are complemented with self-evaluation sheets that make students to think about their own learning. At the same time it provides feedback to teacher. In the activity on Faraday´s law of electromagnetic induction students investigate the voltage induced in a coil situated between the poles of a turning horseshoe magnet. They analyze the experimental results for different parameters (frequency and number of coil turns) and reflect on the concepts and skills understanding in the self-evaluation sheet.

4 Conclusion
The experience from the implementation shows that teachers still need training in the field of IBSE and formative assessment strategies to fully understand their purpose and how to adjust teaching based on their implementation. We have designed online teacher education webinars where these issues are presented and discussed in detail.

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Strategies for Assessment of Inquiry Learning in Science

Abstract. Active learning methods receiving more and more attention require a design of assessment methods tailored to their goals and evaluation of the entire learning process. In the SAILS project, 19 science learning units in the inquiry-based learning approach were designed together with the whole spectrum of assessment tools. Each unit was tested in 3-8 classes, and the teachers reported their experiences in case studies. Teachers proved to be able to conduct the IBL lessons and use the assessment tools designed for formative assessment, however, their preferences for evaluation

differed.

1 Introduction
In the last few decades, active learning methods have been receiving more and more attention as the best approaches to developing XXI-century skills. Unlike traditional methods, which are the most effective in delivering content knowledge at low levels of Bloom's taxonomy, active learning methods support developing competencies in their holistic form, comprising content knowledge, skills, and attitudes. They transform the classroom into a student-centered environment, in which students engaged collaboratively [1], discover the world by inquiry [2], and thus create their own learning paths. However, when active learning methods replace the traditional teaching approach, standard evaluation focusing only on content knowledge becomes inadequate. The mindset for assessment needs to change from standardized tests to the assessment tools evaluating the entire learning process, also during this process. So next to the summative assessment, a lot of teacher attention should be devoted to formative assessment. Such an approach has tremendous power in learning - as found by Black and William in their meta-analysis [3], intentional use of evaluation in the classroom (formative assessment) to promote learning unequivocally improved student achievements.

2 Inquiry-based learning and assessment
Inquiry-based learning (IBL) has been one of the most advocated active learning methods in science education over the last two decades is [4]. It leads to knowledge and understanding of the world by asking inquiry questions, formulating hypotheses, and testing them by collecting data during scientific experiments and using them as evidence to explain phenomena or events. In general, learning by inquiry follows a research cycle the researchers employ when they study a scientific problem. The concept of this pedagogy is not new; however, its educational potential has been increasing in technology-based societies [2]. It has been associated with increased students' motivation and interest in science, supporting the development of inquiry competencies and conceptual understanding [5].
As in any other learning environments and teaching/learning strategies, assessment in the IBL involves a collection of data, its analysis, formulation of conclusions and a feedback given to the students. Formative assessment (also called 'assessment for learning' [6]) serves the improvement of the learning process and is linked to the instant feedback given to students during this process. It can become relatively informal through on-the-fly interactions (informal formative assessment conversations [7]) or can be implemented more formally – with the help of evaluation tools and assessment plans prepared in advance (e.g., rubrics [8]). However, if used in the IBL approach, it should also reflect the goals and nature of this pedagogy [9-10].

3 Research and results
During the SAILS EU project [11], 19 science learning units in the IBL pedagogy were designed together with many ready-to-use assessment tools embedded into the material. More than 2500 teachers in 12 countries participated in SAILS teacher education programs with the IBL practical training based on the developed material. Each unit was implemented by 3-8 teachers and reported as case studies. The assessment focused on a particular set of inquiry skills and competencies in every learning unit was proposed and associated with recommended evaluation tools. Brainstorming and classroom dialogue were assessed using checkboxes (Electricity unit) and less formally (on-the-fly) in most other units. In half of the units, teachers implemented self- and peer-assessment tools for the evaluation of collaborative work. Worksheets and other student-devised material were evaluated with rubrics in almost all cases. In one-third of case studies, teachers collected their assessment data in observations.
Most of the teachers followed the units and assessment strategies proposed in the ready-to-use materials, and a few of them willingly adapted units or assessment tools to their purposes. In general, the frequency of implementation of the assessment methods spoke for teachers' preferences. A closer look (e.g., Electricity unit) into case studies revealed that some of them felt uncomfortable with the evaluation tools the others reported as favorable.
So, the conclusion is that, when designing teaching materials user-friendly and beneficial for as many classes as possible, a broad spectrum of assessment opportunities should be included, both for formative and summative evaluation of the IBL approach.

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Dulong-Petit's law and Boltzmann's theoretical proof from the Kinetic Theory of Gases – Historical implications to the teaching physics in high school and its didactic transposition

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Abstract. The main aspect that we will discuss in this work is the presentation of the law of specific heats by Dulong and Petit, from an experimental and theoretical point of view, comparing with the publication of Ludwig Boltzmann's doctoral thesis in 1866. According to Cássio C. Laranjeiras [1], it is in his thesis that Boltzmann will do the analytical demonstration of this law for the first time. Determined experimentally by the two French physicists and published on April 12, 1819 [2] this law it very important to the after development of physics and will have fundamental implications to the quantum mechanics and can be considered the starting point for changes in the interpretation of Newton's classical mechanics.

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Astronomy Teaching - A didactic proposal for measuring the Equinox in Latin America

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Abstract. The purpose of this work was to create an experimental sequence that would allow Basic Education students (Elementary and High School in Brazil) to make daily measurements of the Spring Equinox in the Southern Hemisphere, involving three Latin American countries, Argentina, Brazil, and Costa Rica. From a spreadsheet created in Excel software, by professors Josué Dionofrio and Diego Galperin [1], respectively professors at the ORT Technical School in Buenos Aires and the National University of Rio Negro, Bariloche, Argentina, students could learn about and determine the trajectory developed by Sun during the day, calculating angles as a function of measurements of the height of the gnome and the width and angle of the shadow cast by the Sun.

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Education and Formation: STEM in the Tradition of Alexander von Humboldt

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Alexander von Humboldt is known as a great naturalist and explorer who wanted to understand and describe the explored space as a whole in many different ways. More than anyone else, he was able to view and examine scientifically correct facts additionally under criteria of aesthetics. Thus, in many respects, he was a pioneer of an interdisciplinary way of working and researching, which is also exemplary for today's teaching.

The central pivot for Humboldt's work is formed by the STEM subjects astronomy, chemistry, geography, forestry and physics. Some historical measurements from the respective disciplines will be presented and compared with current measurements. While in his time Humboldt was only able to determine heights by means of a barometer and by calculating angles, today remote sensing methods such as the stereoscopic evaluation of (digital) aerial image pairs and the calculation of digital terrain models as well as radar data are available. Technological progress makes possible not only the calculation of the earth's surface, but also the determination of phytomass. We are able to reproduce Humboldt's measurements and to perfect them with modern methods. In the sense of the scholar, regularities and regularities can be represented cartographically, among other things, which are to be thematized in science and technology lessons. Furthermore, they offer points of contact for neighboring sciences and bear witness to Alexander von Humboldt's extensive work and scientific foresight.

Analogous to the wealth of material in the STEM subjects, Humboldt was able to grasp the totality of a landscape with all its phenomena and processes and to draw conclusions from it that are still valid today. For example, the mapping and publication of the three-dimensional distribution of vegetation, the global change of the earth's magnetic field, the temperature change with the geographical latitude or the ocean currents go back to him.

The breadth of Alexander von Humboldt's impact makes him an iconic figure as a figure in the various STEM subjects, creating occasions to advance integration while respecting the respective sciences.

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STEMization of Physics teaching: Effectiveness and challenges

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Symposium
STEMization of Physics teaching: Effectiveness and challenges
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Abstract: STEM education has been implemented popularly since about 2005. STEM education fosters individuals in learning achievements, authentic problem-solving skills, interests in STEM sub-subjects, and pursuing STEM careers. Nowadays, many countries have deployed STEM education, including Asian countries, to achieve STEM values for students. With the development of STEM education, an ongoing challenge to pre-service science teachers (PST) is developing STEM teaching practice. Therefore, it is a significant concern to develop appropriate strategies for PST training programs in STEM education. We designed and implemented internationally the method course that strengthens modeling-based inquiry and integration of STEM education in Vietnam and Indonesia. The key features of the MII-STEM approach consist of real-world problems, constructing a STEM model, predicting, collecting data, testing solutions, and formulating hypothesis-proposal solutions. The results showed that PSTs positively changed perceptions of models and modelings. Besides, Indonesian PSTs had microteaching at acceptable levels.
However, successful STEM education required national conditions. One solution could be the implimention of specific subjects with the key features of STEM education, for example, innovative Physics teaching with STEM integration. In the following parts, we presented empirical studies of implementing STEM education in Vietnamese classes. Such empirical studies affirmed the successful implementation of STEM education in Vietnam.

Speakers:
Nguyen Thi To Khuyen: Impacts of method courses on Vietnamese pre-service teachers' perceptions and practices: From the perspectives of model and modeling in STEM education
R. Ahmad Zaky El Islami: MII-STEM Implementation in Indonesia: A Pilot Study
Nguyen Anh Thuan: Building STEM teaching materials for the topic "Energy and life" to develop scientific competencies of junior high school students
Tuong Duy Hai: The role of Coach 7 software in STEM education for a primary and secondary school in Vietnam

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Education and Formation: STEM in the Tradition of Alexander von Humboldt

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The breadth of Alexander von Humboldt's impact makes him an iconic figure as a figure in the various STEM subjects, creating occasions to advance integration while respecting the respective sciences.