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Strategies for Active Learning and Assessment of the Learning Processes

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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Primary authors: Prof. FAZIO, Claudio (University of Palermo, Department of Physics and Chemistry, Palermo, Italy); Prof. SANDS, David (University of Chester, Department of Mathematical and Physical Sciences, Chester, U.K.); Prof. SAPIA, Peppino (University of Calabria –Department of Biology, Ecology and Earth Science, Rende (CS), Italy); Prof. BOZZO, Giacomo (University of Calabria –Department of Biology, Ecology and Earth Science, Rende (CS), Italy); JESKOVA, Zuzana (Pavol Jozef Safarik University in Kosice, Faculty of Science, Kosice, Slovakia); Prof. SOKOLOWSKA, Dagmara (Smoluchowski Institute of Physics, Jagiellonian University, Kraków, Poland); BATTAGLIA, Onofrio Rosario (University of Palermo, Department of Physics and Chemistry, Palermo, Italy)

Presenters: Prof. FAZIO, Claudio (University of Palermo, Department of Physics and Chemistry, Palermo, Italy); SOKOŁOWSKA, Dagmara; Prof. SANDS, David (University of Chester, Department of Mathematical and Physical Sciences, Chester, U.K.); SANDS, David (independent); Prof. SAPIA, Peppino (University of Calabria –Department of Biology, Ecology and Earth Science, Rende (CS), Italy); JESKOVA, Zuzana (Pavol Jozef Safarik University in Kosice, Faculty of Science, Kosice, Slovakia); Prof. SOKOLOWSKA, Dagmara (Smoluchowski Institute of Physics, Jagiellonian University, Kraków, Poland); BATTAGLIA, Onofrio Rosario (University of Palermo, Department of Physics and Chemistry, Palermo, Italy)