Hands-on Physics Experiments for Classroom

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Introduction

Many studies have pointed out the fact that traditional instruction fails when it attempts to reach desired objectives regarding in-depth knowledge of theoretical concepts or positive attitudes towards science [1-4]. Different proposals are needed to favour interaction, motivation, and autonomy, and these should be alternatives to the traditional classroom (based essentially on exposition, examples and solving practical cases) where subject matter is usually presented as pieces of knowledge with no relation to the everyday setting. This means that students who can solve problems and practical cases successfully are not able to answer simple conceptual questions correctly [5-8]. These difficulties are similar in various countries, yet the speed at which the necessary changes are applied varies [9]. This is the case even though the conditions for good learning (well structured basic fundamentals, adequate motivation, promotion of autonomous activity and interaction among peers) are sufficiently understood [10]. This problem appears to worsen when student numbers are high. These changes are often rapidly driven by conditions outside the educational world. In particular, recent developments in Information and Communication Technologies (ICTs) lead one to think that they will be widely used in future learning for simulations, virtual tutoring, video games, on-line labs, etc.

Fortunately, the understanding of course contents for Physics can be improved by employing active/cooperative/collaborative approaches, where learners are involved in varied activities led by a teacher who is seen as a tutor or guide. Such supervision can become one of the most demanding, complex and sophisticated tasks and requires, therefore, that the teacher's role is given greater recognition [11]. There are strategies that enable this process to be carried out successfully by using interaction, experimentation and demonstration to increase the information retained, improve marks and eliminate negative attitudes towards disciplines. In particular Hands-on Physics Experiments (HPEs) influence the fact that the authority is the real world, and they have played an important role in curricula for scientific/technological subjects [12-13]. Many projects have shown the benefits of their use to attain quality learning [14-15]. An HPE involves the use, both inside and outside the classroom, of any material, object, instrument or experimental setup used for learning a properly contextualized concept, principle, law or application [16-17]. They contribute to the student's use of basic concepts and experimental skills to construct something new, and so give the pupil a chance to integrate theoretical and practical contents naturally, as indicated by current trends that have influenced the development of recent educational curricula [18].

In this work we present several ways of using HPEs based on our experience, taking into account the way in which people learn (Fig. 1): considering their previous knowledge, using interaction among peers (solving problems in collaboration with others) and with real tasks, provoking cognitive conflict, and promoting conceptual change if needed. An updated view of resources will be shown, which assumes that teachers do not only need a methodological change in their teaching practice but also in their pedagogical beliefs and knowledge be achieved.

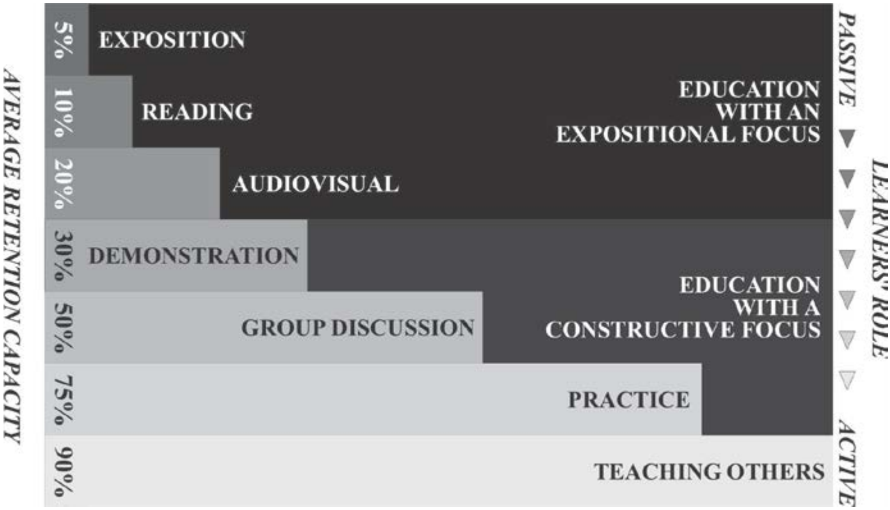

Figure 1. Learning methodologies [19]

Resources

The use of ICTs has been a basic catalyst in the recent evolution of the educational sphere. At present they are generally used as either a source for support material or an on-line resource for conceptual learning. One of the tasks teachers have is to give training in how to make reliable searches using ICT. It is important to identify clearly which tools favour learning by introducing materials, methods and concepts into the classroom in terms of real situations the learners are familiar with. In this way the subject is made interesting and the learner's work and curiosity are stimulated. This does not mean teaching learning methods or techniques, but instead means fostering the use and development of these strategies by teachers in their daily practice. When it comes to implementing innovation of this type, teachers encounter a series of difficulties that have to be overcome: ignorance of the tools placed at their disposal by modern learning theories; strong resistance to change; lack of understanding of their integration in learning processes; or a lack of clear methodology for assessment. In the case of HPEs there are countless resources that can be used in the classroom (Tab. 1). The origin of present day HPEs possibly lays in the interactive centres that play an important role in informal learning contexts and offer, furthermore, a chance to update the public in general and build bridges between Science and Education [20]. Interactive centres offer the chance to connect theoretical and practical concepts, and show their contents by relating them to daily applications through the use of small-scale, semi-guided personal research. Much of the material developed in this context has successfully been exported to the educational world and has acted to drive the change taking place [21-22].

BOOKS ⇨	[23-25]
SPECIALISED JOURNALS ⇨	[26-28]
EVENTS ⇨	[29-31]
PROJECTS ⇨	[19,32-33]
ASSOCIATIONS ⇨	[34-36]
WORLD WIDE WEB ⇨	[37-39]
AUDIOVISUAL MATERIALS ⇨	[40-42]
SUPPLIER OF EDUCATIVE EQUIPMENT ⇨	[43-45]
INTERACTIVE MUSEUMS ⇨	[46-48]

Table 1. Available resources

Strategies

HPEs can be employed for different learning modes that require different organizational structures: in master classes, in proposals for autonomous work, in small groups or in collective works. They are all oriented towards action and have the clear purpose of acquiring skills and increasing commitment to the subject. This diversity of strategies is the best way to respond to the various motivations and interests of the learners. Alone they do not contribute significantly to improved learning, and if they are to be effective, then there needs to be a clear definition of aims, interests and motivations. Only in correctly structured curricula do they contribute to success as one more piece in the puzzle. Here, we can at least document their use in the following modes (Fig. 2):

a) Demonstrations. HPEs have traditionally been used in a demonstrative format during master classes, helping students to confirm or reject previous ideas, obtain useful information and venture new conclusions [49-53]. For the teacher, this requires limiting and organizing the material being presented and linking new and old knowledge, while avoiding the use of unnecessary terms or excessive detail that can lead to distractions. In many cases these are short demonstrations that do not interfere in the flow of the subject and provoke an increase in the learner's interaction as they introduce physical activity that often means standing up and moving a short distance. The contents thus take on a new dimension and become an opportunity to motivate and generate class discussion if they are complemented by thought-provoking questions. Among other things, such demonstrations allow pupils to observe activities that would not habitually be carried out in the lab because of their danger, cost or delicate nature: using apparatus that show simple concepts but that require complex handling, or the reproduction of historic experiments, for example.

Figure 2. Some examples of HPEs

b) Interactive demonstrations. The above demonstrations may be more effective in master classes if their interactivity is increased. In an interactive HPE [8,54-56] the teacher gives detailed explanations beforehand about the elements of the HPE and the steps to be taken, linking the scientific and technological concepts to be used if they have already been developed; learners are challenged to make predictions about the expected result; the teacher divides the activity into small steps, intersperses questions to maintain attention and check understanding, works to ensure the process is interactive for the learners, and encourages, if possible, the experiment itself. Once the interactive HPE is over the learners discuss what has happened with their nearest classmates and the teacher moderates the ensuing debate. This process promotes conceptual understanding by means of a combination of mental and hands on activities to produce information from the discussion amongst peers. Learners must fill out a sheet listing the expected results, using individual response cards or one of the commercially available electronic student response systems [57-59].

c) Problem-based learning (PBL) mini-projects [60]. Challenge HPEs, in which learners working in small groups are simply given a project title (usually from a list taken from a book [23] or webpage [46]) that they must create, write up, (linking it to other contents and providing complementary information) and present the results for, once they have found and used the necessary resources. Much of this new teaching material should include images, sound, video, text and ICT elements. These include interactive web domains or online virtual simulation tools [61-63]. These complementary, virtual HPEs enable phenomena to be analyzed intuitively both graphically and numerically (which leads to more in-depth understanding). By using them, learners become familiar with computational tools in support activities that allow them to modify and explore parameters like those in the real HPE. The development of simulations can even be carried out by means of several ICT applications that can either be used by the teachers or the students [64-65]. During these PBL format HPEs the learners, with teacher supervision: construct a model, measure, make hypotheses, estimate, discuss and suggest. This requires additional intellectual effort and offers a more creative and contextualized vision of the practical component than that offered by work in the lab. This latter type of work is often a mechanical labour directed towards obtaining, without reflection, expected results that have quantitative verification in the way of a response that completes a pre-designed and directed experiment [66]. Fortunately, such cases do not require costly or specialized equipment and in the case of Physics concepts there are a large number of well documented proposals to provide to learners, leaving them with the responsibility to design and create the final product independently.

d) Collective HPEs, Science Week. With the results of work undertaken by learners, a “cloning” of a small Science/Technology museum can be organized in the educational centre itself, in an activity that is both collective and cooperative and one in which learners are co-responsible for its definition, assembly and overseeing, within a framework of explanation by peers or equals [67-71]. Such design and interactivity work with learners is advantageous in attaining important learning goals related with the skills needed for activities of this type, and well as strengthening other basic competences used across the learning process: these could be instrumental (capacity for analysis and synthesis, problem solving, or organization and planning capacity, etc.), or personal (teamwork, interpersonal relationship skills, critical reasoning, etc.), or systemic (autonomous learning, creativity or initiative, and enterprise spirit, etc.) Each module is accompanied by a self-explanatory panel that, under an eye-catching heading, contains brief audiovisual information and a few provocative questions that attempt to lead participants to reconsider their mental models by seeking connections with the contents of the formal learning that are not obvious, as an essential step before recompiling the new information. Complex explanations, difficult instructions or highly sophisticated setups are avoided as they could inhibit potential participants from exploring unaided. The information provided is fun and attractive in order to increase and stimulate the visitors' attention, and it is related in some way to their previous experiences. More than learn, the visiting pupil is stimulated to delve deeper and develop a context for their own exploration in their own way, leading, if possible, to follow up activities done by themselves. Visitors are accompanied by the learners who act as guide or mediator and are provided with methodological models for communication with the visitors. They also promote alternatives to the spontaneous activities or make any adjustments that may be needed. The learners are given prior instruction so that they can give understandable scientific explanations [72-75].

e) Corridor HPEs. Some of the HPEs designed by the teachers, or by the learners themselves, can later be set up throughout the centre’s building during term time [76-78]. These selected modules will be a permanent exhibition that can facilitate the learner's voluntary interaction at any time. Incentives for their use can be given by organizing a competition among the centre’s community, in which participants must solve simple challenges regarding the concepts that underlie the HPEs.

Conclusions

Hands-on Physics Experiments, (HPEs) in any of their possible usage modes, can be an additional tool for facilitating learning of scientific and technological contents in any educational setting. Their main advantages are appropriate contextualization, flexibility and learner motivation. The learner is an interacting part of the process in which the monotony associated with the master class is broken. HPEs attempt to demonstrate that science and technology can be interesting, exciting, easy to understand, and subjects that are important in everyday life and also something that can be beneficial by putting the student in an active, critical learning position: experimenting, making hypotheses, interpreting, and reaching conclusions. They also attempt to convey scientific knowledge as basic for anyone in today's technological world. Of course, the contribution of HPEs is relevant when the learners themselves are the main participants in the process and the teacher is focused on proposing this learning environment and activating the learners.
Although there is a general lack of institutional support, time and teacher training in this type of learning strategies that deal with real subjects, an increase in their use has been observed because they increase the commitment of the agents involved, their capacity for learning to learn and the dynamics of the educational process. Using suitably organized and contextualized HPEs bridges the gap between theory and practice and leads to beneficial changes in the basis and the way that students learn. Involvement and participation in subjects is considerably increased according to opinions stated in several learner surveys, and likewise there is a contribution, without doubt, to the professional development of a teaching community who in most cases can escape, in this way, from the reproduction of models they suffered during their training.

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