Teaching ‘Nature Science’ poses a great challenge to education professionals. In a search for alternatives that can facilitate student’s learning and attract their interest, a trial experience is described that was conducted in the class of BA Degree in Pedagogy at the University of Seville. It was based on the creation of motivational and attractive – Learning and Knowledge Technology (LKT) – materials in the discipline of Nature Science. The results show the advantages that prospective teachers find in the use of Information and Communication Technologies (ICTs) for teaching and learning, in this case, Nature Science.

1. Introduction

The difficulties associated with learning Nature Science are a shared concern both for researchers in the field of science education (teaching) and for teachers at different levels of education. In this regard, at both secondary school and university levels, there arise such problems as high repetition and drop-out rates, poor learner performance, difficulties associated with reading comprehension and oral and written expression, etc. All this results from the failure to use methodological approaches that can contribute to meaningful learning as against those that leads to mechanical rote learning. It is, therefore, necessary to focus on the use of strategies that contribute to the real knowledge of the processes (cognitive and metacognitive) involved, rather than just the products or results. This line of work was discussed by Dibar Ure and Cappannini [1] at the 7th Symposium on Research in Educa-

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In the last few decades, the world has changed, and the State’s education administration has decided to ‘fill’ classrooms with Information and Communication Technologies (ICTs): digital whiteboards, computers, video projectors, and, perhaps most extraordinary, laptops with Internet connection in the students’ backpacks. The intention behind all these changes is to prepare students for a new type of society – the information society – and train them in using ICTs as effective learning tools (see Table 1).

But teachers’ attitude to all these changes so loaded with innovative connotations has been very different. The 2011 report on the TICSE 2.0 project [3] concludes that:

“Traditional teaching materials (such as textbooks and blackboards) are still the most used resources in the ‘School 2.0’ classrooms despite the abundance of digital technology and the indication of most teachers that the greater part of the activities done in class with ICTs could be framed within a didactic paradigm that we could consider classic.”

The idea that there exists an ‘emerging pedagogy’ following in dialogue with, the latest generation of ICTs. This pedagogy is impregnated with the ideas of great pedagogues of the 20th century, but goes beyond them in certain aspects. This is reflected in Physics where they described studies showing that science teaching is still predominantly transmissive based on blackboard explanations, textbooks, and solving closed problems. The need for this methodological change in the teaching and dissemination of science is presented by Oliva and Acevedo [2] in their study published in the journal Eureka.

We cannot precisely state the reasons behind this situation. Some are related to the teachers’ training and professional motivation, while some to the overload of content in the official curricula. Some are related to the enormous difficulties involved in attending to diversity in the laboratory. Sometimes it occur while trying to reconcile innovative approaches with the requirements of some external evaluation. In short, there are many reasons yet to be studied.

Production and evaluation of media and materials, emergent technologies, curricular integration of ICTs, science education, higher education, primary education.
<table>
<thead>
<tr>
<th>Scientific Dimension</th>
<th>Type of ICT</th>
<th>Specific Tools</th>
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<tbody>
<tr>
<td>Inquiry (real world)</td>
<td>ICTs for data collection and experimental analysis of real phenomena</td>
<td>Digital cameras, digital magnifying glasses and microscopes, peripheral sensors, mobile phone internal sensors, remote labs, video analysis programs (like Tracker), audio analysis programs (like Audacity), streamed remote cameras, etc.</td>
</tr>
<tr>
<td>Inquiry (virtual world)</td>
<td>ICTs for displaying and experimental analysis of virtual phenomena</td>
<td>Java animations, simulations and phsylets, molecular viewers, virtual laboratories, scientific video games, virtual micro-worlds of physics (Interactive Physics, Physion, Algodoo) virtual environments like Virtual or chemistry (ChemLab), GreenHouse, QuestAtlantis, WISE, GasLab, or ElectroCity, etc.</td>
</tr>
<tr>
<td>Modeling</td>
<td>ICTs for the expression of models with digital support</td>
<td>Tactile devices for the graphical presentation of models (tablet, IWB, etc.), concept map editors, programs designed for computational modeling (Modellus, VnR, Stella, NetLogo, etc.), programming languages (like Scratch or Alice).</td>
</tr>
<tr>
<td>Argumentation</td>
<td>ICTs for argumentation and communication in the science classroom</td>
<td>Tools for collaborative work (like Drive, Wikis, Patlet, etc.), social networks, digital whiteboards connected to personal devices, specific interaction apps, online voting systems, etc.</td>
</tr>
</tbody>
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Table 1. Classification of ICTs in the framework of scientific practice.
the innovative practices undertaken by intuitive teachers who are sensitive to the changes that our society is experiencing and the possibilities offered by technology. This idea is captured in the book Tecnologías Emergentes Pedagogías Emergentes? [Emerging Technologies: Emerging Pedagogies?] by Adell and Castañeda [4].

In the work A Definition of Emerging Technologies for Education by Veletsianos [5], a specific definition of ‘emergent technologies’ is proposed for education. Emerging technologies are tools, concepts, innovations, and advances used in diverse educational contexts to serve diverse purposes related to education. This will be the definition that we shall work with.

However, one should not confuse emerging with new. Although many ‘emerging’ technologies are ‘new’, the mere fact of being new does not automatically make a technology emergent. Thus, emerging technologies in education may be new technological developments or applications of known technologies to promote education.

To avoid any questions on the need of using ICT-centred educational innovations in classrooms and in various subjects, we shall rely on the book on virtual psychology by Coll and Monereo [6] which proposes a third way. According to this, innovations are not to be considered innovative per se, nor just as another factor in the process.

“The incorporation of ICTs into education neither transforms nor automatically improves educational processes, but does instead substantially change the context in which these processes take place, the relationships between their agents and between them and the tasks and content to be learnt, thus opening the way to the possibility of an eventual in-depth transformation of those processes, and which may or may not turn out to be an effective improvement depending on the specific uses made of the technology.”

teacher which showed how the interactive nature of technological tools facilitates pupils’ access to information, and development of scientific procedures, and competencies, while fostering their interest in learning science.

Webb [8], in the *International Journal of Science Education*, notes four main possible effects deriving from the use of ICTs in science teaching: “promoting cognitive acceleration; enabling a wider range of experience so that students can relate science to their own and other real-world experiences; increasing students’ self-management; and facilitating data collection and presentation.”

According to Romero and Quesada [9], in their article published in *Revista Enseñanza de las Ciencias* on new technologies and meaningful science learning, simulations, modeling, and virtual laboratories allow misconceptions to be detected and help in the understanding and application of scientific theories. In addition, images make abstract models and theories more visible, making it easier for the students to assimilate them and establish connections between the macroscopic or physical and the microscopic or theoretical.

From this perspective, it is interesting to present the classification of ICTs in the framework of scientific practice that was recently put forward by L´opez Simó et al. [10] during the 10th International Congress on Research in Science Didactics. The framework makes it possible to identify the kinds of ICT tools that facilitate the development of certain dimensions of scientific practice.

As indicated before, there have been numerous studies highlighting the advantages of incorporating ICTs with respect to the content of different scientific disciplines.

In chemistry, for example, Da Rocha and De Mellado [11] observes that simulations, games, animations, and experiments that appear in the digital resources accompanying textbooks benefit learning, being better than the latter because they allow for exploration and, therefore, understanding. In this same event, Vinícius [12] highlights the benefits of mobile devices in the teaching and learning of science.
learning process, and Silva and Carneiro [13] argue for the use of WebQuests, showing that these formats contribute to making the teaching and learning process more attractive, comprehensive, and exact.

In environmental sciences, the article published by Carey and Darner Gougis [14] in the *Journal of Science Education and Technology* entitled ‘Simulation modeling of lakes in undergraduate and graduate classrooms increases comprehension of climate change concepts and experience with computational tools’ found that the “use of computational modeling to explore the effects of climate change may be a new instructional strategy that can stimulate learning and improved comprehension of complex topics that are difficult to understand from static datasets”.

Returning to the experiences presented at the 10th International Congress on Research in Science Didactics, Zanotello *et al.* [15] presented an interesting study on students using various ICT tools for the construction of a website on a specific topic in the field of nature sciences. They highlighted that while working with ICTs, the students took in and used scientific terms, exercised their capacity to choose, participated actively in the learning process, enjoyed the benefits of interdisciplinarity, and improved in their self-esteem, autonomous and critical thinking, and sense of responsibility.

Finally, the aforementioned work of Romero and Quesada [9] collects together various investigations that support the effectiveness of technologies in improving skills related to solving quantitative problems, to the concepts and procedures concerning the measurement of physical variables, to the spatial skills of geography and astronomy, and to understanding key concepts of physics and chemistry. They highlight the need, through successive cycles of application, evaluation, and revision, to continue refining and improving different ICT tools used for teaching and learning sciences. They also refer to the important part teachers play in the use of ICTs, and the need to advance their training so as to improve the integration of ICTs in teaching nature sciences.
GENERAL ARTICLE

It was on the basis of these conceptions and with the intention of contributing to the use of ICTs in teaching nature sciences that the experiment described below was carried out. We believe that using innovative ideas in which the students can actively participate, creating their own knowledge, is one way to implement emergent technological practices in education. The activities mentioned below were designed with the belief that experiences based on constructivism can strengthen collaborative learning. Every time a new technology (cinema, radio, TV, computers, tablets, blogs, wikis, etc.) has burst into our lives, it has been received as an opportunity to improve education. In terms of their histories, technologies and educational changes have always gone hand in hand.

2. Development of the Trial Experience

We shall now describe the trial experience that we conducted in the academic year 2015–2016 at the Faculty of Education Sciences (University of Seville, Spain) as part of the analysis and design of curricular materials and assessment in social and experimental sciences, corresponding to the 4th year Bachelor’s degree course in Pedagogy.

The objective was to design and develop curricular materials as an alternative to textbooks for teaching and learning Nature Science. We planned a trial experience in which our students were required to design and construct play-type Learning and Knowledge Technology (LKT) materials for learning the subject. The exercises were meant to help the students develop a set of competencies formally entitled ‘E05: Design, development, management, and evaluation of plans, projects, programs, resources, and materials for educational and/or formative action in diverse spheres and contexts’ in their plan of studies.

A total of 57 students participated in the trial. They chose a particular topic from the curricular content of Nature Science1 and designed teaching and learning materials for 12-year-old students using one of the following emerging technologies: Wiki, web page, or interactive whiteboard (IWB).

1 Official syllabus of the 6th year of primary education (Royal Decree 1262014, February 28, establishing the basic curriculum of primary education [16].
Once the groups had been set up, and the curricular content and technology with which to design the materials selected, the trial experience was implemented in three phases:

**Phase 1. Planning and Organizing the Task.**

This first phase laid the foundations as described by Cabero [17] for the procedure to follow in the design, production, post-production, and evaluation of the ICTs as LKT teaching media. In short, with the LKTs, we wanted our students to use technology in both teaching and learning processes, ensuring their acquisition of the basic competencies so that they can improve their teaching qualitatively and quantitatively (Espuny, Gisbert, González, & Coiduras) [18]. We also addressed the two types of designs our material should respond to – communicative design and the learning design – as established by Bartolomé [19]. In the former case, the students were required to respond to such questions as: What kind of information do we want to convey with our material? Which is the most appropriate medium? How will the user interact with the material? and so on. In the latter, they focussed on actual learning, setting out the objectives and the competencies to work towards, the content going to be addressed, etc.

**Phase 2. Preparing the Materials**

Prior to the design phase, various class seminars were held discussing the technology to use (e.g., Wiki design on the Wikispaces server, web page design with Wix.com) and design of the material for the smart board IWB. The most basic aspects regarding the use of each of these technologies were dealt with.

Our students were encouraged to use multimedia tools which would allow their future 6th year primary education students to interact with the material. In particular, manipulating, viewing, touching, and browsing the content should foster pupils’ motivation for Nature Science, leading to it having a more personal meaning for them. The materials designed by each group was later be evaluated by the instructor and by the rest of their classmates.
Box 1. Website on the Theme ‘Ecosystems’ Designed Using Wix.com

Nature Science help us to understand the world we live in, our environment and the contributions that scientific and technological advances have made to our everyday life. This example presents teaching material designed with Wix.com on ecosystems, as part of ‘Block 3: Living Beings’ of the primary education curriculum. The curriculum elements worked on are:

- **Content:**
The relationships between living beings, food chains, populations, communities, and ecosystems. Characteristics and components of an ecosystem. Ecosystems such as grassland, pond, woodland, coastline, and city and living beings.

- **Evaluation Criteria:**
Know the characteristics and components of an ecosystem.

- **Learning Standard:**
Identifies and explains the relationships among living beings, food chains, populations, communities, and ecosystems.
Identifies and explains some of the causes of species extinction.
Observes and identifies the main features and components of an ecosystem.
Recognizes and explains some ecosystems: grassland, pond, woodland, coastline, and city, and the living beings inhabiting them.
Observes and identifies different habitats of living beings.

**Figure A.** Web page on ecosystems designed using Wix.com.
Box 2. Wiki Designed to Explain the Representation of the Earth.

This example presents WikiTierra, designed with Wikispaces, on the representation of the Earth in ‘Block 2: The World in Which We Live’ of the primary education curriculum. The curriculum elements worked on are:

- **Content:**
  The planet Earth and its satellite, the Moon, characteristics, motion and its consequences.
  Representation of the Earth and rientation in space.
  Terrestrial globes, identification of the poles, the axis, and the hemispheres.

- **Evaluation Criteria:**
  Locate the planet Earth and the Moon in the Solar System, explaining their characteristics, motion, and consequences.
  Identify the spheres of the Earth according whether their structure is internal or external.
  Explain the different ways of representing the Earth’s surface.
  Properly describe maps, interpreting their scale and conventional signs.
  Identify and use the concepts of parallels, meridians, and geographic coordinates.

- **Learning Standard:**
  Defines and represents the motion of terrestrial translation, the axis of rotation, and the geographic poles, and associates their combined effect with the seasons of the year.
  Explains day and night as a consequence of terrestrial rotation, and as units for the measurement of time.
  Defines the motion of the Moon by identifying and naming the lunar phases.
  Identifies, names, and describes the spheres of the Earth.
  Explains the different representations of the Earth, maps, terrestrial planispheres, and terrestrial globes.
  Identifies and classifies the different types of maps, including terrestrial planispheres, defines what the scale is on a map, and uses and interprets the commonest conventional signs that may appear on it.
  Locates different points on the Earth using parallels and meridians and geographic coordinates.

![WikiTierra interface](image)

Figure B. WikiTierra interface.
Box 3. Interactive e-activities

The students designed and selected play-type activities for teaching science to primary school students. Some examples can be seen in Figures C, D, and E.

**Figure C.** Interactive game for evaluation of knowledge on mammals. Source: SuperSaber.com

**Figure D.** Association-type activity to work on functions of nutrition on life and organs. Source: Mario Ramos Rodríguez (M2R, 2007).

**Figure E.** Activity designed with the Hot Potatoes software package on the representation of the Earth.
1 and 2 present some of the topics which were worked on in the class, and Box 3 indicates different activities that the students selected and designed.

At the conclusion of the post-production phase of each of the materials, the rest of the students evaluated the medium used. If the evaluation was positive, the material was taken as finished. Otherwise, changes were made, and the production phase started again.

**Phase 3. Evaluation of the Trial experience.**

In order to evaluate the trial experience, different instruments were used that allowed us to determine our students’ degree of satisfaction and the knowledge they had acquired. The first was the semantic differential scale that has been applied in previous experiences by Cabero and Gutiérrez [20] and Barroso and Gutiérrez [21]. This instrument allows one to measure the meaning that the situation or the fact put to the participants has for them. Thus, once the experience was over, we gave our students the list of adjectives as well as the orientations necessary for them to be able to indicate which, in their opinion, was the adjective that most closely approached their perception of each pair proposed.

3. Results

The results of the trial experience were very positive. As it can be seen in Table 2, the means obtained were fairly high, with the overall mean being 5.96 out of 7.

In addition to the semantic differential, the students were asked to submit a final report describing the material they had created, and justifying each of the elements they had designed. This report allowed us to evaluate the degree of knowledge and the depth of understanding of the subject. As the final point of the report, the students were asked to share what the experience meant for their future as pedagogues. Their responses were analysed and coded in accordance with the following categories determined from the
Table 2. Means of the semantic differential scale.

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slow-fast</td>
<td>57</td>
<td>2</td>
<td>7</td>
<td>6.02</td>
</tr>
<tr>
<td>Inaccessible-Accessible</td>
<td>57</td>
<td>3</td>
<td>7</td>
<td>6.07</td>
</tr>
<tr>
<td>Passive-Active</td>
<td>57</td>
<td>2</td>
<td>7</td>
<td>6.38</td>
</tr>
<tr>
<td>Distractive-Attractive</td>
<td>57</td>
<td>1</td>
<td>7</td>
<td>6.23</td>
</tr>
<tr>
<td>Doubtful-Reliable</td>
<td>57</td>
<td>3</td>
<td>7</td>
<td>6.59</td>
</tr>
<tr>
<td>Deformative-Formative</td>
<td>57</td>
<td>4</td>
<td>7</td>
<td>6.78</td>
</tr>
<tr>
<td>Time wasting-Time saving</td>
<td>57</td>
<td>3</td>
<td>7</td>
<td>6.31</td>
</tr>
<tr>
<td>Boring-Entertaining</td>
<td>57</td>
<td>5</td>
<td>7</td>
<td>6.31</td>
</tr>
<tr>
<td>Stiff-Flexible</td>
<td>57</td>
<td>1</td>
<td>7</td>
<td>5.05</td>
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<tr>
<td>Overwhelming-Doable</td>
<td>57</td>
<td>5</td>
<td>7</td>
<td>6.45</td>
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<tr>
<td>Awkward-Agile</td>
<td>57</td>
<td>1</td>
<td>7</td>
<td>5.05</td>
</tr>
<tr>
<td>Unnecessary-Necessary</td>
<td>57</td>
<td>2</td>
<td>7</td>
<td>6.02</td>
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<tr>
<td>Unpleasant-Pleasant</td>
<td>57</td>
<td>5</td>
<td>7</td>
<td>6.31</td>
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<tr>
<td>Misleading-Informative</td>
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<td>5</td>
<td>7</td>
<td>6.45</td>
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<tr>
<td>Ineffective-Effective</td>
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<td>5</td>
<td>7</td>
<td>6.45</td>
</tr>
<tr>
<td>Complicated-Simple</td>
<td>57</td>
<td>1</td>
<td>7</td>
<td>4.12</td>
</tr>
<tr>
<td>Worthless-Valuable</td>
<td>57</td>
<td>3</td>
<td>7</td>
<td>6.07</td>
</tr>
<tr>
<td>Pernicious-Educational</td>
<td>57</td>
<td>4</td>
<td>7</td>
<td>6.78</td>
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<tr>
<td>Difficult-Easy</td>
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<td>Impractical-Practical</td>
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<td>Negative-Positive</td>
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<td>6.38</td>
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<td>Useless-Useful</td>
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<td>Hindrance-Facilitator</td>
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<td>Inappropriate-Appropriate</td>
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<td>Trivial-Important</td>
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<td>Inaccurate-Exact</td>
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<td>Dispensable-Indispensable</td>
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<td>7</td>
<td>6.31</td>
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<td>Impersonal-Personal</td>
<td>57</td>
<td>1</td>
<td>7</td>
<td>5.05</td>
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<td>Detrimental-Beneficial</td>
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<td>5</td>
<td>7</td>
<td>6.40</td>
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<td>Stupidity-Smartness</td>
<td>57</td>
<td>2</td>
<td>7</td>
<td>6.31</td>
</tr>
<tr>
<td>Uncomfortable-Comfortable</td>
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<td>3</td>
<td>7</td>
<td>5.07</td>
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<tr>
<td>Uninteresting-Interesting</td>
<td>57</td>
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<td>7</td>
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<tr>
<td>N valid (in the list)</td>
<td>57</td>
<td></td>
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</tbody>
</table>
data which had been acquired:

- **Knowledge acquired on the topic that had been the object of study:** The students refer to the knowledge they have acquired on the topic that they took as the basis for designing the multimedia material.

- **Knowledge acquired using the technologies applied to the field of education:** The students mention the acquisition of skills and tools that allow them to use those technologies for teaching.

- **Transfer of knowledge acquired to their professional future:** The students explain that the knowledge acquired is useful for their future as pedagogues in different contexts.

In their reports, the students stated that they had learnt more about the topic under study by having to master it in order to design activities and locate the resources: “This task led us to go more deeply into our theme of ‘Ecosystems’ because if we did not have control of that then it would have been quite complicated to design activities and organize the material we designed” (Group 17). “Designing a website on the function of nutrition has led us to master the scientific language of the subject and, in designing animations and other interactive resources, to understand the different processes involved” (Group 8). Similarly, all the reports made some reference to the development of skills and abilities related to technologies applied to education: “We have learnt to handle tools that we would never have imagined, this experience has made us lose our fear of ICTs and discover their educational possibilities” (Group 1). “It has not been easy to integrate different tools into the same space, but we have really succeeded, we have learnt to integrate them and to give it a true educational sense” (Group 10). Finally, more than half of the reports alluded to transfer of the knowledge acquired to their professional future: “The best thing about the work we did is the usefulness we see [in] it for our future, it is one of the few really practical experiences that we have done throughout our university education, it has been a great help to us” (Group 11). “Learning to integrate
ICTs in the subject of Nature Sciences seems very useful for our professional future, since today’s children use ICTs in their daily lives and in doing so in the classroom, we will encourage learning” (Group 5).

All this leads us to value the trial experience very positively, and to consider implementing it again, overcoming the small obstacles encountered, and repeating those factors that the students considered positively.

Suggested Reading


