CHAPTER 5

5. INTEGRATION OF ICT IN SCIENCE EDUCATION LABORATORIES BY PRIMARY STUDENT TEACHERS

The chapter is published as:

Integration of ICT in Science Education Laboratories by Primary Student Teachers

Abstract
Integration of Information and Communication Technologies (ICT), such as datalogging systems in science teaching laboratories has a long-standing and ongoing history. However, teachers’ views and practices should be examined in order to achieve higher levels of efficacy and meaningful implementation of ICT in schools. In the present study, 12 primary student teachers along with an expert design and develop lab teaching material by implementing datalogging systems. The extent to which they integrate datalogging, as well as the nature of integration of ICT that they adopt is been studied through qualitative analysis of group discussions and quantitative analysis of the science experiments developed. Findings of the study reveal that student teachers addressed difficulties in ‘actively’ integrating technology in a non-negligible number of experiments, not only due to lack of content and technological content knowledge needed, but also due to cultural incompatibilities with the innovative and student-centered affordances of datalogging. Student teachers also held limited views of technology and regarded dataloggers mostly as measurement tools and not as a tool for inquiry. Moreover, student teachers’ prior experiences on using ICT as well as their prime emphasis on PCK strongly affected the design of experiments, indicating a PCK to TPACK approach.

5.1 INTRODUCTION
Practical work, i.e. experiences in school settings in which students interact with equipment and materials or secondary sources of data to observe and understand the physical world (Hofstein et al., 2013) has traditionally been a distinctive goal in science education (NRC, 2012) due to the multiple benefits that it offers. Increased students’ motivation and interest, development of better understanding on scientific concepts, development of science inquiry skills and perceptions of nature of science (Hofstein et al., 2013) are some of them. Moreover, the science laboratory has always been a fruitful context for integrating contemporary technological tools, in order to increase learning gains, but also in cultivating practical and technological skills (Sokoloff et al., 2007).

In fact, technology has always been interconnected with science in authentic scientific practices. Hence, educational reforms during the 80s and 90s which aimed to the assimilation of scientific practices in schools (NRC, 1996) high valued the integration of technological tools in the school laboratory. Since then, technology has increased rapidly, and technological tools with innovative features and usability have ‘invaded’ science education. Therefore, integrating technology in
science education kept been a long-standing and continuous goal for researchers whilst several calls strive for effectively implementing Information and Communications Technologies (ICT) in education (Waight & Neumann, 2020). Similarly, in recent Integrated STEM approaches i.e. teaching approaches in which students are encouraged to understand and develop interconnections between STEM disciplines (Martín-Páez et al., 2019), integrating technology is an issue of high importance.

However, successful enactment of technology in schools is still an ongoing and complex endeavour, since several parameters of the classroom ‘ecosystem’ i.e. teacher, students, context, should be taken into account (Waight & Abd-El-Khalick, 2012). Specifically, the role of the teacher is regarded as a determining agent of the effective adoption of the educational innovation of ICT, since his understandings and beliefs highly affect the meaningful integration of ICT (Ertmer & Ottenbreit-Leftwich, 2013; Juuti et al., 2016). Therefore, it is imperative to study teachers’ views and practices on implementing technology, the difficulties that they encounter, as well as the interaction with the other elements of the ecosystem. Moreover, it is of additional value to focus on preservice teachers’ views and practices on implementing technology in order to develop informed preservice teacher training programmes that will prepare future generations of teachers able to make meaningful use of the affordances of the ICT tools.

5.1.1 Datalogging systems

In the present study, ICT tools used in the school laboratory relate to datalogging systems, also known as Microcomputer-Based Laboratory (MBL) systems or computer-aided practical work. In specific, datalogging systems consist of: a) electronic sensors (wired/wireless), b) data collection and analysis devices, such as computers or more recently, portable “smart” devices as tablets, smartphones and c) the appropriate data collection and analysis software (Ye et al., 2019). Their main affordance is that data can be collected and represented in real-time; hence, the visualisation of phenomena can contribute to increased students’ understanding (Donnelly-Hemosillo et al., 2020). By using datalogging systems, students can study relations between variables easily and avoid time-consuming procedures (Barton 2005), and they are supported to conduct their own investigations that are difficult to achieve without technology (Donnelly-Hemosillo et al., 2020). Furthermore, students are given the chance to cultivate laboratory skills, such as selecting variables, materials, methods and tolerated experimental errors (Chen et al., 2014), as well as to improve their graph skills and to use dataloggers for predicting the evolution of the experiment, contributing to inquiry-based approaches (Nicolaou et al., 2007; Sokoloff, 2017).

Using dataloggers can also contribute to improvement of students’ modelling and symbolic language skills (Bisdikian & Psillos, 2002; Liu et al., 2017; Wong, Chen, et al., 2020; Ye et al., 2019) by connecting the underlying mathematical modeling with the related phenomena and therefore, integrating theory with practice (Lavonen et al., 2003; Sokoloff et al., 2007), by using multiple
modalities: both concrete and abstract/mathematical (Ye et al., 2019). Therefore, datalogging systems can additionally promote the cultivation of interdisciplinary thinking and skills to students (Wong, Quast, et al., 2020).

Using datalogging also reduces time for data collection and procedural tasks and results in the quick repetition of the experiments in order for the students to concentrate on the underlying concepts and discuss on them (Chen et al., 2014; Nikolaou et al., 2007; Tortosa, 2012). Moreover, a wider range of experiments may be performed, as well as the fact that some experiments may be performed with more safety in comparison with conventional laboratory settings and manipulation of hazardous materials (Barton, 2005; Tortosa, 2012).

Further technological advances on dataloggers have also resulted in innovations such as the portability of dataloggers, which may extend the capabilities for science and mathematics education by concurrently reducing the high cost of the equipment without reducing the level of precision on data collection (Liu et al., 2017). Concurrently, attitudinal benefits also arise, since using datalogging can motivate students (Chen et al., 2014; Wong, Chen, et al., 2020), including students from minority groups or students with educational disabilities (Barton, 2005).

5.1.2 Technology Integration

Regardless of the potentialities that innovative ICT tools offer, technology integration is to a great extent context-specific, and in many cases it may turn to be problematic. Particularly, the act of integrating ICT does not necessarily promote inquiry-based learning and increased student science achievement, whilst in some cases it can restrict it (Odom et al., 2011; Waight & Abd-El-Khalick, 2007). Hence, it is imperative to study the factors affecting the successful implementation of ICT in order to achieve efficacy. Under this prism, a) teacher’s knowledge and attitudes towards technology, b) the classroom contextual environment and pedagogy, as well as c) the features and usability of ICT tools themselves should be taken seriously under consideration when integrating ICT.

First, the role of the teacher has far been stressed as crucial, since he is regarded as the important agent of the educational innovation, such as ICT (Juuti et al., 2016; Lavonen et al., 2003). In specific, teacher’s technological knowledge (Ifinedo et al., 2020) as well as teacher’s beliefs and attitudes in using technology (Farjon et al., 2019; Prestridge, 2017) are stated as defining factors for technology integration in schools.

Considering teacher’s knowledge for science teaching, the Pedagogical Content Knowledge (PCK) framework has long been used in teacher education as both: a) a knowledge base used in planning for and the delivery of topic-specific instruction in specific classroom contexts and b) a skill, the act of teaching that occurs in the specific content and classroom context. Furthermore, in recent updates of the framework, topic-specific professional knowledge is defined as the canonical knowledge needed to teach specific topics according to specific students’
developmental level. Particularly, topic-specific professional knowledge is characterised as relatively static, visible and related to public understanding held by the community in contrast to PCK which is more dynamic and personal knowledge. Moreover, topic-specific professional knowledge interacts with ‘teacher professional knowledge bases’, such as Pedagogical knowledge, knowledge of assessment, content, curriculum and students. Subsequently, the teacher’s topic specific professional knowledge is been affected by teacher amplifiers and filters, i.e. teacher’s prior knowledge, beliefs and attitudes in order to be transformed to PCK applied during the classroom practice (Gess-Newsome, 2015).

Similarly, in the field of technology integration, the Technological Pedagogical Content Knowledge (TPACK) is the form of knowledge needed in order to effectively teach science content with the use of ICT and derives from the combination of Technology, Pedagogy and Content knowledge. Additional subordinate intersections of knowledge domains are also defined as: a) Technological Content Knowledge (TCK), which is knowledge on how science and technology influence and constrain one another, e.g. restrictions but also affordances that technology offers in representations of content as well as how the content dictates or even changes the technology used, and b) Technological Pedagogical Knowledge (TPK), which is knowledge on existence, components and capabilities of various technologies as used in teaching and learning settings as well as how teaching can be affected by using these technologies (Koehler et al., 2013).

Second, the context and the pedagogy that ICT are used, affects the learning gains from using ICT in classrooms. Often, even when teachers use ICT in the classroom, they do not tend to make efficient use of them. Teachers tend to use ICT in a “passive” way, e.g. for presentations, reading texts and completing worksheets, which do not seem to improve student achievement (Odom et al., 2011; Papanastasiou et al., 2003). The same occurs with early-career teachers that, even though they feel confident about their skills in using ICT, they restrict the use of ICT in lesson preparation (word processing) and mail communication and not in the science classroom, where research shows great potential for student learning (Dawson, 2008). The above practices rather reflect traditional teacher-centered practices and do not improve students learning, nor they promote inquiry (Odom et al., 2011; Prestridge, 2017; Waight & Abd-El-Khalick, 2007). On the contrary, when ICT are been used in a student-centered pedagogy, with the active participation of the learner and following an inquiry stance, results are positive (Ertmer & Ottenbreit-Leftwich, 2013; Odom et al., 2011; Waight & Abd-El-Khalick, 2018; Zucker et al., 2008). For example, particularly using MBL with an emphasis on observation and prediction, as well as for taking into account students’ alternative ideas contributes substantially to students’ learning with Technology (Bisdikian & Psillos, 2002).

Furthermore, embedding ICT in an authentic and social context, in which participants are encouraged to collaborate and interact reflectively in authentic science contexts for science learning assists them to integrate ICT meaningfully (Bell et al., 2013; Iliaki et al., 2019). Moreover, contextual factors regarding the high costs of MBL still hinder implementation of MBL (Tortosa,
2012), even though new generation of cost-effective devices tend to solve this problem (Liu et al., 2017).

Finally, concerning ICT tools and their innovative features, their effectiveness and usability in relation to the general ecological factors (teachers and students’ knowledge, attitudes and culture, general context) should be examined. In specific, many technologies used in schools are not primarily designed under an educational perspective. For example, some word processing software were designed for business purposes, whilst some web-based technologies e.g. blogs and pod-cast are made for entertainment, communication and social networking purposes (Koehler et al., 2013). Therefore, when implementing a technology, it is imperative to consider the purposes, culture and values that they represent comparing to the ones that are needed in the system to be implemented, i.e. the school and teacher culture, beliefs, knowledge and expertise (Waight & Abd-El-Khalick, 2018; Waight & Neumann, 2020). Hence, recent updates of the TPACK model also incorporate contextual knowledge, as well as interactions with culture and organisations in a more systemic approach (Mishra, 2019; Warr et al., 2019).

### 5.1.3 Aim of the study

Therefore, the present study investigates the integration of technology in the science laboratory by primary student teachers. Student teachers work in groups in a science teaching laboratory in order to design and develop science experiments with the use of datalogging systems. Furthermore, student teachers collaborate with peers in order to reflect on the design of the experiments and the use of dataloggers on the experiments. Subsequently, they implement them for science teaching to school students.

In specific, the study investigates the extent to which primary student teachers integrate ICT when designing laboratory teaching material as well as the nature of technology integration, in terms of active/passive use of ICT, implementation of innovative features such as using datalogging systems for prediction/inquiry processes and portability. Furthermore, analysis of student teacher discussions about their developed teaching material aims to shedding light on their views and deficiencies towards technology integration. Therefore, the research questions are:

- **RQ1)** How do primary student teachers integrate datalogging in order to design and develop science laboratory teaching material?
- **RQ2)** What difficulties do they encounter when designing and developing science laboratory teaching material with the use of datalogging?

### 5.2 THEORETICAL FRAMEWORK

Theoretical framework of the present study is the Model of Educational Reconstruction for Teacher Education (Van Dijk and Kattmann, 2007), modified and adapted to the needs of the present study. The general characteristic of the model is trying to bring science-related issues and
educationally-oriented issues into balance, whilst it addresses the gap between science education research and science instruction practice (Duit et al., 2012). According to the model, the following five elements interact dynamically: a) First, the clarification of the subject matter, the analysis of its educational significance and the reconstruction of the science content by taking into consideration students’ misconceptions and interests, science processes and views on nature of science. In addition, in the context of technology integration, we consider imperative to also examine the technological innovations as well i.e. their features and usability for their educational significance and purpose in the context of science education. The reasoning behind such an approach is that, according to researchers of philosophy and nature of technology, technological advances in school classrooms often follow a faith-based approach and often neglect the ‘baggage’ that these technologies bring along, such as “the specific purposes, context, knowledge and expertise of the specialized agents, culture and values as well as financial, professional and social structures that ushered and nurtured the use and adoption of these technologies” (Waight and Abd-El-Khalick, 2018). Therefore, the ICT tools, i.e. their features and use should also be analysed and reconstructed in order to meet educational needs of science education. b) Empirical studies on students’ misconceptions and interests, teachers’ views and beliefs of the science concepts and students’ learning as well as teaching and learning processes and the role of instructional tools, in our case dataloggers. Furthermore, studies about students’ learning with the use of technology as well as students’ attitudes and views on technology should be taken into account in order to maximise the effectiveness in integrating technology for science learning. c) The design and evaluation of learning environments, which in our case refer to technology-integrated learning environments, in continuous and dynamic interrelation with the aforementioned two elements. d) Studies about teachers’ PCK, their knowledge, beliefs and experiences, along with technology integration and TPACK studies in the present study, the knowledge needed to effectively teach science content with the use of technology. e) The design and the production of guidelines for teacher education programmes, which in the present study refers to technology-integrated teacher education programmes.

Figure 1

Model of Educational Reconstruction for Teacher Education (Van Dijk and Kattmann, 2007), as Modified and Adapted to the Needs of the Present Study
Therefore, the central aspects of the presented model shown in Figure 1 is that it gives emphasis on the educational reconstruction of the subject matter, empirical studies on teaching and learning as well as the examination of how technology facilitates science learning.

5.3 METHODS

The study was carried out during an undergraduate science laboratory course and lasted one academic semester, i.e. 13 weeks. Participants were 12 female student teachers during their 4th year of studies at a primary education academic department. The student teachers had previously attended a science content course about introductory science content knowledge, a science teaching methodology course and a course about general use of educational technology, e.g. using software for developing activities and quizzes, developing a webpage etc. However, they had no previous training on datalogging systems or using other ICT tools specifically in the context of the science laboratory. As related to the Greek primary educational system, it is highly recommended, albeit not mandatory, for graduated primary teachers to implement ICT in classroom and cultivate ICT-related skills to students. Hence, this course is part of the courses that student teachers may assign to in order to develop their digital competences.

The student teachers formed small groups of two, whilst all six student teacher groups formed a Learning Community (LC) (Couso, 2016), together with a science education researcher. The researcher played the role of the expert in the domains of science, school laboratory and ICT during the LC meetings, whilst during the lab sessions his role was marginalised, since he provided assistance mostly on technical/procedural issues. For the needs of this paper, student teacher groups are represented with a number (1 to 6), whilst each student teacher was additionally assigned with the letter a or b, e.g. 6a represents a student teacher in group 6. Similarly, the researcher was represented as R.

The course consisted of an introductory phase, three design phases and an implementation phase, as shown in Figure 2. The introductory phase lasted two weeks and included both a
classroom lecture and a lab session about datalogging and laboratory equipment, in which student teachers got acquainted with sensors and basic features of dataloggers, such as connectivity, real-time data collection and various representations of data (graph/digits/meter). Subsequently, each design phase lasted two weeks and comprised two weekly lab sessions (3 hours each). In this phase, student teachers were called upon to design and develop teaching material, i.e. science experiments and indicative worksheets with the use of datalogging in six branches of Science: Mechanics, Waves/Oscillations, Optics, Electromagnetism, Thermodynamics and Chemistry. After the completion of each design phase, there was a cyclical shift of the branches of science between the student teacher groups. Furthermore, in order to give emphasis to inquiry-based teaching, student teacher groups were called upon to submit a bibliographic review of students’ alternative ideas in the specific branch of science they were assigned in the beginning of each design phase. Finally, during the implementation phase, the student teachers applied the developed teaching material in teaching school students during educational school visits in the university science teaching laboratory.

Importantly, in order to support collaboration between peers and expert guidance, an LC meeting was held between the design phases, in terms of reflection on student teachers’ practice and additionally, in providing feedback and ideas for the subsequent design phases. A final reflective LC meeting was also held for the student teachers to share their overall experience and views about integrating ICT in the school laboratory.

**Figure 2**

*Implementation of the Study*

5.3.1 ICT tools

In the present study, considerations of technology are specifically referred to the digital age and within the educational context. In particular, student teachers were called upon to integrate ICT tools, such as datalogging systems. Datalogging systems of the study consist of Pasco (www.pasco.com) sensors (wireless/wired) along with data collection and analysis devices (tablets/laptops/smart devices), in which the appropriate data analysis software is installed, Pasco Sparkvue in specific. However, student teachers improvised in some cases by using real-time datalogging through their smartphone applications, e.g. DaTuner Lite.
5.3.2 Data Collection and Analysis

Data was gathered during the academic semester that the course was implemented through: a) the developed teaching material i.e. science experiments, as presented through the powerpoint presentations in the LC meetings, indicative worksheets and lab reports, b) transcribed discussions during the LC meetings, c) researcher’s field notes about student teachers’ ICT integration practice during the lab sessions for triangulation, d) initial questionnaire about the student teachers’ views and attitudes concerning ICT and experimentation.

Integration of technology in the developed teaching material was analysed in two levels: First, the extent to which student teachers managed to integrate datalogging and/or ICT in general in the design of science experiments. Second, the use of datalogging was further analysed, in terms of: a) whether datalogging were used in a meaningful or procedural way, i.e. whether using datalogging for data collection and analysis assisted the completion of teaching goals or whether they were integrated “passively”/in a procedural way, without offering an additional value to the design of the experiment, respectively, b) whether datalogging tools were also used for inquiry purposes, such as to predict students’ misconceptions. In particular, dataloggers had a feature that offered the students the opportunity to draw the evolution of the physical value in the graph, so that they could subsequently interpret and compare the results with their predictions, c) whether student teachers made meaningful use of innovative features of the tools, such as the portability of the sensors/devices in this case.

For the needs of the analysis, the developed teaching material was initially analysed and triangulated through several sources i.e. descriptions in the LC/presentations/worksheets/lab reports, and a matrix of science experiments (n=90) was created in SPSS software. Each of the experiments was coded across several binary variables declaring the existence of absence of this category/feature, while the design phase was coded as ordinal variable. Due to the nature of the variables, non-parametric K independent samples Kruskal-Wallis tests were used among the design phases, as well as between student teacher groups.

Moreover, in order to gain more in-depth insights about student teachers’ views and attitudes towards integration of ICT, qualitative content analysis (Mayring, 2015) of student teachers’ discussions in the LC meetings was carried out. In specific, themes derived from discussions that were made during the LC meetings and were related to the research questions, i.e. their views and difficulties on integrating technology, were initially identified inductively. Subsequently, the themes were re-analysed and grouped in regard to the issue involved and hence, inferences were produced inductively. Additionally, characteristic typologies that represent extreme or important statements according to the literature were also took under consideration. Furthermore, data from student teachers’ discussions were also analysed in the light of the results from the quantitative analysis in order to increase validity.
5.4 RESULTS

5.4.1 Integration of ICT

In relation to the total number of developed experiments, student teachers managed to integrate dataloggers in the majority of the experiments (n=56), as shown in Figure 3, whilst in some cases (n=5) ICT tools were used, but not in the context of datalogging, e.g. use of video recording and editing in fast forward mode or lab instruments with digital measuring, such as a four-digits scale.

Figure 3

Integration Ratio of ICT in the Experiments

Hence, we can see in Figure 3 that despite the predefined goal of integrating ICT in the experiments, in a non-negligible number of experiments integrating ICT was not made possible. In an effort to interpret this difficulty, we can see from the analysis of student teachers’ reflections that non prior experience with datalogging, as well as lack of TCK on how to use datalogging acted as hindering factors for the integration of ICT. Noteworthily, these deficiencies do not refer to using educational technology in general –since student teachers had previous academic training in using general ICT tools and software in education, but it is rather referred specifically to using datalogging systems actively in the school laboratory, which seems to require a different skillset.

Student teachers also stated shortage in CK as impeding factor for the design of ICT-rich experiments. Moreover, they also expressed several concerns on understanding some specific topics or branches of science that indisputably affected the design process and implementation of ICT, according to their reflections.
5b: Electromagnetism. In general, I don’t get along well with Physics.
R: you mean the content?
5b: yes, the content, it was difficult for me as a branch of science. I mean, if I didn't have, if I had to do it my own, I wouldn’t had made it.

2b: Yes, I faced great difficulty in the experiments that we had to develop for Chemistry in specific. In the others I had no problem.

The above reflections indicate deficiencies in the context of specific content topics, which denotes the impact of Topic-Specific Professional Knowledge (Gess-Newsome, 2015) in the present study. However, it seems that in some cases the topics did not only affect the general design of the experiment, i.e. PCK, but also specifically affected the integration of ICT as well.

6a: Optics was difficult also for the integration of ICT
R: As content? What exactly do you mean?
6a: for the ICT as well [...] 6b: we couldn’t find how to integrate ICT [...] The kids were bored with the spectrometer [...] It is a different thing to try with the prism to make a rainbow and different thing with the spectrometer in which we expect the result from the tablet.

It seems that the specific content concepts and representations also affected the integration process of ICT, in a similar way that they affect the development of PCK (Gess-Newsome, 2015). Noteworthy is also the fact that divergence was noted about which topics student teachers addressed most difficulties, as different student teachers stated different topics/branches of science that they addressed problems, which could be interpreted by diverse levels of knowledge, experiences and previous representations in these topics that each teacher had. The above divergencies among student teachers indicate both the complexity and the specificity of the task of integrating ICT in the context of teaching science content, i.e. developing TPACK.

Moreover, we can see from the above quotations of 6b that another impeding factor is apparent, which is more related to their attitudes and views about ICT, as also commented below:

5a: Because I interact with little kids, I have nephews and I see that many things that I try to explain to them, they understand it more easily if I show them simple things, if I tell them simply, not so sophisticated.
5b: it has to do with the age I think.
3b: I believe that as younger they are, the better is to use simpler materials in order to relate them with their everyday life.

4a and we couldn’t find, I mean the experiments that I did in primary school was far more simple
4b with candles
4a with candles, with torches, means something that you couldn’t integrate tablets for sure

In specific, 5 student teachers seemed to hold quite conservative views about little kids’ familiarity with technology and they emphasised using ‘simple’ i.e. non-digital instructional materials from students’ everyday life as more comprehensible for younger kids. On the other hand, this view neglects the contemporary routine of little kids which is surrounded by digital technologies, as well as the ICT skills that kids develop from their daily interaction with ICT tools. There seemed to be an incompatibility of views on what is regarded as familiar for kids today. This ‘generation gap’ (Prensky, 2001) between digital ‘immigrants’ and ‘natives’ seem to have influenced student teachers’ views about ICT, their applicability and affordances for children education. Therefore, we consider reasonable to hypothesise that this hierarchy of status between ‘simple’ instructional materials and ICT tools had also impacted the integration ratio of ICT. In addition, as made clear from the above statements, student teachers’ previous experiences either as students themselves or as practitioner teachers with simple instructional materials tended to influence their views on the implementation of ICT.

Consequently, we can see from the above quotations of 6b, 5a, 3b that student teachers’ personal amplifiers and filters i.e. their prior representations, experiences and knowledge as well as beliefs and attitudes towards ICT should also been taken under consideration, since they may also affect the development of TPACK knowledge by facilitating or impeding the integration of ICT in the teaching material, in the same way that they affect the development of PCK (Gess-Newsome, 2015). In this light, we can identify not only content-specific difficulties but also difficulties related to personal culture and values about technology (Waigh & Abd-El-Khalick, 2018).

**Figure 4**

*Integration of ICT According to Design Phase*
Furthermore, analysing the evolution of the integration ratio of ICT per design phase, we can see in Figure 4 that the integration ratio of MBL remained considerably the same among the three design phases (p=0.936). However, student teachers stressed that there was an increasing difficulty in later phases in designing non-trivial experiments in relation to the ones that their peers had already designed in previous design phases. Hence, preserving integration ratio in similar levels could be interpreted as a successful endeavour, in which collaboration between peers played an important role, as has been analysed in previous work (Nipyrakis & Stavrou, 2019).

5.4.2 Use of ICT in the experiments

Further analysis concerning the use of datalogging implemented by student teachers in the experiments, reveals that in 14% of the experiments, datalogging was used passively/in a rather procedural manner, as shown in Table 1. That means that ICT were integrated as an external task without meaningfully contributing to the accomplishment of the teaching goals of the experiment. For example, a student teacher group used a sound intensity sensor in an experiment where the goal was to show that sound waves cause oscillation in the materials that they are transmitted, e.g. in sugar grains over a speaker.

Table 1

Use of Datalogging in the Experiments

<table>
<thead>
<tr>
<th>Experiments</th>
<th>% of total experiments with dataloggers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design phase A</td>
<td>Datalogging (X)</td>
</tr>
<tr>
<td>Design phase B</td>
<td>Datalogging (X)</td>
</tr>
<tr>
<td>Design phase C</td>
<td>Datalogging (X)</td>
</tr>
</tbody>
</table>
Meaningful/‘active’ use of datalogging  48  85,7%
Procedural/‘passive’ use of datalogging  8  14,3%
Using datalogging for prediction of students’ views  8  14,3%
Use of portability  3  5,4%

Total sum of experiments  56

<table>
<thead>
<tr>
<th></th>
<th>Phase A</th>
<th>Phase B</th>
<th>Phase C</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meaningful/‘active’ use of datalogging</td>
<td>17</td>
<td>14</td>
<td>17</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td>94,4%</td>
<td>77,8%</td>
<td>85,0%</td>
<td>85,7%</td>
</tr>
<tr>
<td>Procedural/‘passive’ use of datalogging</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>5,6%</td>
<td>22,2%</td>
<td>15,0%</td>
<td>14,3%</td>
</tr>
<tr>
<td>Using datalogging for prediction of students’ views</td>
<td>0</td>
<td>4</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>0,0%</td>
<td>22,2%</td>
<td>20,0%</td>
<td>14,3%</td>
</tr>
<tr>
<td>Use of portability</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>5,6%</td>
<td>5,6%</td>
<td>5,0%</td>
<td>5,4%</td>
</tr>
</tbody>
</table>

Total sum of experiments  18  18  20  56

Student teachers’ reflections in the LC meetings also confirm this passive use of ICT, as stated below:

6a: In some cases it [technology] was necessary for sure, but there are others that you were saying let’s put that so that it exists
5b: just add a prediction
6a: Let’s add a sound sensor so that it is there, so I did.

5b: [...] In the first phase about Chemistry, actually we used it [technology] for measuring. Then in Thermodynamics we also had it for comparing and predicting [data]. In Electromagnetism also measuring and predicting.
R: That is important right? That many of you used it [technology] just for measuring or using it for measuring that it was not actually needed, I mean it was not necessary
In many cases, ICT came as an external obligation that did not contribute to meaning-making or the experimental procedure, but just fulfilled the task of the course. Moreover, as shown in Table 2, this percentage of ‘passive’ use of datalogging was not reduced, albeit the reflections and the discussions that took place during the LC meetings. On the contrary, the cases of passive use of datalogging increased (p=0.367), since complexity rose in latter design phases due to developing non-trivial experiments already designed by peer groups, as mentioned previously. In order to address this increasing difficulty in latter design phases, increased demands of TCK appeared, which in a non-negligible number of cases resulted to ineffective and procedural integration of ICT.

As related to the usability of features of dataloggers, using dataloggers as an inquiry tool through the prediction of the graph feature, i.e. making use of the touch screen to anticipate the evolution of this physical magnitude, was implemented to a limited extent (14.3%). Student teachers stressed the importance of previous explicit training on specific features of datalogging in order to integrate it in the design. However, albeit the extended discussions in the LC meetings about this feature, it was not given serious attention in the production of the teaching material in the subsequent phases (p=0.113). That doesn’t mean that student teachers did not use the inquiry phases of engage and prediction of students’ alternative ideas in their worksheets, but they usually did that without the use of datalogging or by misjudging the use of datalogging, e.g. one teacher group initially thought that students could draw the path of the light beam in the tablet, which was not a feature of the specific datalogger systems. In general, we can infer from the discussions that student teachers regarded datalogging systems mostly as a tool for measuring data and not as an integral tool of the inquiry procedure.

Similarly, making productive use of the advances that the portability feature offered was quite restricted (5.4%). Student teachers did used wireless devices (sensors/tablets), but they rarely made meaningful use of the fact that they were portable, in order to facilitate a wider range of experiments or further modify the experiments made. Although several ideas for making use of the wireless nature of sensors and devices were discussed in the LC meetings, e.g. using sound/temperature sensors in sealed objects or underwater or using motion sensors for out-of-class environments, student teachers did not make use of that innovative feature. We could interpret this result in two ways: first, we could hypothesise that implementation of this feature requires higher levels of expertise i.e. TPACK and second, this feature might haven’t gained high status from the student teachers under a static traditional indoor lab infrastructure setting. However, this finding contradicts the fact that young people do use a vast range of portable devices in their everyday routine, which implies that implementing these technologies for teaching requires additional levels of TPACK. Further research on teachers’ implementation of this
innovation is required in order to shed light on its potentiality in lab and out-of-class environments.

### 5.4.3 Developing TPACK

Analysis of the discussions that took place during the LC meetings also shed light to insights about the process of developing TPACK that the student teachers followed. In specific, answering the question posed in the final LC meeting: ‘which factors did you take under consideration when designing your teaching material?’, almost all student teacher groups (n=5 out of 6) in their presentations placed main emphasis and primary hierarchical order on pedagogical issues e.g. student misconceptions, the age and level of students and teaching method and so did mentioned most student teachers (n=9) in the LC discussion as well. This result is rational, since it reflects their agency as primary teachers.

Moreover, from statements of 8 student teachers we can infer that integrating ICT was rather a subsequent process, since their first goal was to find experiments on that domain or experiments based on students’ misconceptions.

4b: Initially, it was difficult to find an experiment. Because ok, we should study the content, get into the spirit. Then we used to find the experiment. The second difficulty was how to integrate datalogging, I mean tablet and sensors, so that it would be an experiment with the use of technology. That restricted us a lot, because many times we used to find very nice and comprehensible experiments for the kids, but we rejected them because we couldn’t integrate datalogging for example.

3b: now, about what we were taking under consideration. First what students believe...In this direction we developed experiments, because we had found other experiments but we didn’t know on what (misconceptions) they were based on.

Most student teachers gave initial focus on finding experiments that would address content and pedagogical goals, i.e. PCK, while integrating Technology was an additional feature that would be integrated –if possible– in a later stage. It seems that most student teachers followed a developing TPACK process starting with existing PCK before introducing Technology to experiments. However, exceptions did take place, since one group of student teachers high valued the integration of ICT to the classroom context and hence, we can infer that they followed a TPK to TPACK process, as made clear in the below statement.
So, the first thing we worried about was to be able to somehow integrate New Technologies and to fit with the age of K-5 and K-6.

However, the general tendency for most student teachers was that ICT was an additional implementation to the experiment, not the primary goal. According to their reflections, the process was to find an experiment primarily addressing pedagogical and content issues and subsequently—if possible, to integrate ICT.

Therefore, a PCK to TPACK model (Koehler et al., 2014) prevailed. Moreover, student teachers tended to return in their previous PCK when they faced difficulties or reached a dead end in implementing technology. These findings are also reflected by the considerable percentages of experiments without ICT and their reflections about the cases that they didn’t manage to integrate ICT. Outputs seem to extent the results of similar studies concerning in-service teachers, where it is claimed that prior beliefs on how content should be taught and learned limited the integration of technology (Niess et al., 2010).

5.4.4 Views on technology

In an effort to further investigate the impeding factors for technology integration, we analyse student teachers’ views on technology in regard to their reflections during the LC meetings. First, as concerns to their training of skills and knowledge on using ICT, almost all student teachers (n=11) claimed that they preferred to be trained to technological applications and features in a rather traditional way, so that knowledge about using ICT should be previously shown to them extensively by the trainer in an explicit way.

2a: in general, maybe, in the first lab that you gave us the tools and said search, try, do things with them, that it should be a little like—not more theoretical, I mean that you showed us the way, because we didn’t have any experience with these. So you could tell us there are these features and these and then we tried to apply them.

6b: in a more traditional way.

3b: Shall I suggest something? You could, the first week that we got to know the lab, the tablets and physics from this point of view, we could get to know tablets better, know the potentialities they have and to have prearranged some content units and to have somehow a preliminary plan of the experiments, so that we come here and say: are these things correct? Should we proceed and apply them?

On the contrary, the nature of integrating technological tools requires more practical skills and effort that derives from experiencing ICT tools, exploring their use in specific and diverse
experimental contexts, as well as dealing with open-ended problems. Hence, a ‘cultural lag’ appeared between student teachers and the technological context. In specific, the course included an initial training phase in which only basic features were shown e.g. wired/wireless connectivity, datalogging, various data display methods, and subsequently gave the student teachers time and tools to further explore their use with the assistance of teaching assistants, also in out-of-programme hours. This rather constructivist approach about the use of dataloggers that demanded personal-driven engagement was not identified as productive for student teachers, whilst there were also requests for additional training before they try to integrate ICT.

Similar approach was preferred for the design of experiments from most student teachers (n=10). The open-ended design procedure caused uncertainty to them regarding content knowledge and experimental procedure issues, which were stated as important obstacles.

3b: [...] I believe that it would be better to discuss them before we make the experiments
R: Yes but we wanted you to do them first and then reflect on them and then let’s say to revisit them
3b: Yes but, we would see before which things from what we designed were correct anyway and then to try to apply them and create them and ok. In a reflection meeting like this now we would just discuss that, you know, it is fine, while, if we knew it from before, we would say I will do that and that. Are they correct? Yes. Should I implement technology? Yes

4a: You could give us some sources, like take the K-5 school book and look that, for example, waves are taught like this
5b: from there (book), find experiments and make some
4b: evolve them

R2: [...] So just because physics teachers in school know what is correct, does that mean that you learned what is correct?
2b: That is the problem, in my opinion, that we are trained in a culture and when we try to do something much different, we need to have a level of certainty on us and so we got difficulties.

Consequently, the constructivist student-centered setting of designing ICT-rich experiments was found demanding for both designing science experiments and technology integration since student teachers were seeking for a priori instruction and materials from the expert. Important is, however, that both content, procedural and technology knowledge was shared during LC meetings in a rather participatory approach, the expert included. Similarly, discussions in LC meetings also focused on how to combine these domains for the design of teaching material, as well as about the implementation of technological features, like using dataloggers for prediction or using portability, as mentioned previously. However, obstacles in designing technology-rich
experiments seemed to be more deep and cultural. It was the traditional educational culture towards adopting educational innovations that was opposed to the student-centered context of designing ICT-rich experiments that hindered the implementation of technology.

Furthermore, an additional factor that dissuaded student teachers from further exploring the datalogging tools was the insecurity they felt in manipulating the tools. In specific, 5 student teachers mentioned that they were afraid of the possibility of damaging the ICT tools and that fear restricted them in further exploring the tools. Especially when one group addressed a problem with a damage on a tablet device, they stated that that made them more cautious afterwards. Problems also occurred when student teachers were experiencing unexpected results due to malfunction of the ICT tools or datalogging errors. 6 student teachers mentioned that issues like these distracted them and made them feel confused. On the contrary, it is a common practice to deal with ICT tools or lab instruments to experience damage, malfunction or error. Once more, there was a cultural incompatibility that made student teachers act more unwillingly and conservatively against integrating and using ICT. Therefore, the above insights constitute—among others—to what we could name as ‘personal amplifiers and barriers’ for cultivating TPACK, is a similar way with that Gess-Newsome (2015) describes as teachers’ amplifiers and filters for PCK.

An interesting view about ICT also appeared in student teachers’ reflections about their teaching practice with MBL.

6b: It makes sense, even we, when we get in the lab that everything is unfamiliar to us, that we see something we haven’t seen before, and someone tells us: watch this tablet, —tablets we already have at home and all kids see that, it is normal that they look around and want to explore. Even we, when we got into the lab we were looking around what is this bar, what is this tap, what is
R: Yes, why?
5b: because it was unfamiliar to us

3b: and they were watching the tablet and they were thinking that we would do, we would listen to music and we will watch youtube with [...]  
2a: mainly youtube
R: so in these cases their interest was disengaged?
3a: yes
3b: yes, it depends from the relation they have with these

According to student teachers, school students do not primarily regard technological tools as educational tools, but they rather interpret the use of these devices for other purposes related to their everyday use e.g. for amusement—at least in first sight. Hence, student teachers addressed
difficulty to relate the use of ICT tools with a teaching goal and to draw students’ interest to ICT tools when compared with lab equipment—which in contrary was quite new and more interesting for them. The same occurred for student teachers themselves during their first impressions towards the lab and the ICT tools, as mentioned. Consequently, the context that ICT tools are framed by users is not always compatible with their educational purpose and therefore, that delimits their educational value or raises the difficulty for using them in the educational context.

Concerns about shortage of tools in schools or the high economical value of ICT tools were also stated by student teachers. In particular, 3 student teachers explicitly expressed concerns whether these tools or practices with these tools in the university could be transferred to schools due to their high cost and availability issues. We could hypothesise that these student teachers regarded the integration of ICT in schools as a rather unrealistic goal and hence that may have delimited their engagement in integrating ICT, a statement that needs further research.

Finally, a considerable number of student teachers (n=6) expressed some characteristic notions about the ICT tools in relation to their content-specific goals, as stated below.

1b: shortage of lab instruments for further implementation and modification of experiments
R: what does that mean?
1a: I mean that
1b: that we wanted to, let’s say I had seen an experiment from another group and we wanted to evolve that more, but we couldn’t find any other instrument that we hadn’t used before. Let’s say in Chemistry we have only the pHmeter, we didn’t have anything else to log data. That we didn’t have many
1a: tools to use
1b: tools in each branch of science. I mean even in Thermodynamics there was only the [digital] thermometer, nothing else. Like in Chemistry there was only the pHmeter, there was nothing else to log data there.

As shown from the above reflections, student teachers often tended to connect the use of a datalogging sensor with a characteristic experiment, which, in cases that it was previously been implemented, its use became subsequently saturated. On the contrary, they didn’t regard a datalogging tool/sensor as a tool that could be used for datalogging of a physical magnitude that could be used for a wide variety of experiments. This view not only denotes lack of TCK, but also reveals rather instrumental views of ICT tools, i.e. emphasising technological tools as mere devices whilst marginalising human contributions and use about their design and operation, as stressed from researchers of nature of technology (DiGironimo, 2011; Waight & Abd-El-Khalick, 2012).
5.5 DISCUSSION

The present study investigates primary student teachers’ integration of datalogging in designing science laboratory teaching material, as well as the factors that affect or impede the integration of ICT. Overall, student teachers managed to make good use of datalogging systems for the design of science experiments in the majority of cases. However, outputs of the study denote difficulties on integrating datalogging systems in a considerable number of cases. Moreover, in a non-negligible number of experiments, ICT was integrated in a procedural way, without adding an additional value to the design of the experiment, which could be characterised as ‘passive’ use.

Students’ reflections in the discussions that took place in the LC meetings reveal several deficiencies related to integrating ICT. First, lack of knowledge, TCK and CK in specific, impeded integration of technology, since they added additional layers of complexity and subsequently impeded the cultivation of TPACK. Noteworthily, TCK knowledge seemed to be highly context-specific, since general knowledge about educational technology did not result to acquaintance with using datalogging for designing ICT-rich science experiments.

Second, student teachers’ previous lab experiences as students or as practitioners with simple non-digital instructional materials, as stated in their reflections, seemed to have shaped representations the safety to which student teachers returned to in cases they reached a dead-end with integrating ICT. The above issue in combination with student teachers’ orientation in prioritising PCK issues when designing teaching material, indicate a PCK to TPACK approach. However, in this approach, teachers’ previous experiences and beliefs often limit their vision to incorporate ICT (Niess et al., 2010). Hence, it would be worthwhile in technology integration programmes to orientate teachers to develop a PCK and TPACK simultaneously model (Koehler et al., 2014) e.g. in cases when they deal with open interdisciplinary topics, in out of the usual curriculum topics, since this way teachers are given the chance to develop both innovative PCK and TPACK.

Third, student teachers often held limited views on technology that indisputably affected their implementation and use in the experiments. Particularly, they mostly regarded dataloggers as devices exclusively for measuring data and not as an inquiry tool appropriate in assisting students to express and compare their misconceptions on empirical phenomena. Furthermore, they tended to relate a device/sensor with a specific experiment and not as measuring a physical magnitude useful in a variety of experiments. The above rather reflect students’ limited views on technology as mere objects/artefacts, marginalising knowledge and human practice contributions (DiGironimo, 2011; Waight & Abd-El-Khalick, 2012). Student teachers also held rather outdated views about students’ familiarity and comprehension on ICT. They tended to interpret technology according to their own era as digital ‘immigrants’ by neglecting the contemporary technological environment kids were born and raised as digital ‘natives’ (Prensky, 2001). Views also on limited
availability in schools and high cost of the devices rather formulated unrealistic views on what they were doing compared to actual school practice, which potentially influenced negatively their attitudes towards ICT. Additionally, student teachers initially held views on ICT for non-educational purposes e.g. entertainment, and so did they mentioned that they noticed about their students, which results on disengagement and limited interest on using ICT for task-related purposes.

Fourth, some critical cultural incompatibilities shouldn’t be overlooked when integrating ICT. In specific, the cultivation of practical technological skills usually requests personal-driven engagement with open-ended problems, whilst often users address failures, malfunction and damage, measurement errors and inaccuracies. Hence, users tend to get acquainted with technology under a rather pragmatic and student-centered approach. On the contrary, student teachers felt insecurity in dealing with technical issues, whilst they rather preferred a more traditional training approach concerning ICT, in which a priori extended training and confirmatory support would be provided. This cultural incompatibility that student teachers addressed was regarded as an important obstacle for integrating ICT.

Finally, it is imperative to interpret the success of technology integration by investigating not only teachers but also the ICT tools themselves, i.e. their features and use in a more holistic and ecological perspective. In particular, the portability feature was not implemented meaningfully in the experiments as it didn’t gain high status and priority under teachers’ point of view. Although we may consider that this feature prerequisites increased TCK in order to be implemented, we also consider reasonable that a feature like this did not seem particularly useful for teachers in a static indoor lab setting e.g. working in the limited space of a lab work bench full of sockets. In other words, this ICT feature did not gain high applicability for student teachers in the ecological environment of a science laboratory. Further research on using portable devices in other indoor and outdoor contexts could shed more light towards the usability of this feature.

Overall, integrating ICT was considered a complex task that is sensitively dependent not only from previous TPACK knowledge, but also views and attitudes on technology, previous experiences and conceptualisations on the role of ICT for learning. Concluding, we could interpret the previous factors as personal amplifiers and filters that can highly influence the formulation of TPACK, in a similar way that they affect the formulation of PCK, whilst interacting also with topic-specific professional knowledge and student outcomes (Gess-Newsome, 2015).

Consequently, integrating ICT could well be characterised both as teacher-, tools- and context-specific and therefore, teacher training programmes should consider more holistic and ecological perspectives in order to achieve efficacy in educating future generations of technological literate teachers.