DETECTING THE IMPLICATIONS OF USING RESEARCH RESULTS TO GUIDE A TEACHING PROCESS IN THE CLASS ON TEACHING SCIENCE

Alba Castelltort[1]*, Conxita Márquez*[1] *and Neus Sanmartí*[1]
[1] Universitat Autònoma de Barcelona

Abstract: An educational experience was carried out within the framework of the Bachelor's in Primary Education at the Universitat Autònoma de Barcelona (UAB). The experience integrated prior research results on the water cycle carried out in primary schools into the training teacher process. The purpose was twofold: firstly, to promote learning in prospective teachers, and secondly, to gather data related to their difficulties and the school experiences which have been most useful in building the water cycle model. This study is part of a study in water-related educational experiences in primary schools. The results show that the innovation has been useful in building the water cycle model and promoting meta-reflection on the learning process with regard to future teaching.

Keywords: Teacher training, water cycle, assessment activities, meta-reflection

BACKGROUND AND FRAMEWORK

This research started with a case study of water-related educational experiences in primary schools in Barcelona (2011-2012). The results of that research show that primary students have limited knowledge about the urban water cycle. That result motivated us to start this research with students in the Bachelor's degree in Primary Education. We wanted to identify these students' prior ideas on the water cycle and, depending on the results, to design a teaching sequence to improve their understanding.

This educational experience took place within the class on Teaching Science in academic year 2012-2013. This class was taught to 60 students in their third year of the Bachelor's degree in Primary Education. The results of diagnosis of the Bachelor's and primary students' knowledge of the urban and natural water cycle were integrated into this sequence to guide the teaching process.

The "cycle" model is a kind of content which is developed within the class as a way of thinking, seeing and organising many types of changes. It permits the regularities and laws governing these changes to be displayed and allows predictions to be made (Marquez et al., 2006). This content is taught through examples related to the materials cycle (rocks, water, carbon, etc.), the biological cycle and the astronomic cycle. To carry out this research, the urban water cycle was also introduced within the content on the water cycle.

Rationale and Purpose

Science Education (SE) stresses the importance of improved adaptation to students' interests and social problems. Lemke (2006) suggests proposals for this and highlights the environmental crisis as one of the priority areas to address: *"Changes are needed in the fundamental understanding and attitudes about the relationship of our species with the rest of the planet's ecology; science education must refocus its priorities in this direction."* In the field of Education for Sustainability (ES), other researchers (Gayford, 2002; Littledyke, 2008; Sauvé, 2010) also highlight the benefits of developing educational processes that integrate SE and ES. In addition, Science Education can and should play a role in providing analytical tools which assist informed decision-making (Sanmartí, Burgoa, & Nuño, 2011).

This research began by identifying knowledge of the water cycle because we believe that knowledge is a necessary condition in order to promote the ability to act, even though we know knowledge alone is not sufficient.

Although a lot of research has been done on students' thinking about the natural water cycle (Bar, 1989; Taiwo et al., 1999; Shepardson, 2009), there is little research into the urban water cycle (Gunckel et al., 2012). Human intervention in natural systems has altered the water cycle in numerous ways. It is important for students to be aware of the key differences between the natural and urban water cycle. This was one of the purposes of the research carried out with primary school students.

In addition to the recent literature, our curriculum framework also reflects the importance of addressing social and environmental issues in primary education. However, this is not enough to promote changes in teaching practices that achieve effective learning on the water cycle from a both scientific and environmental perspective. As Simonneaux and Simonneaux say (2012), the practice of teaching content depends on teachers' knowledge, epistemological assumptions and educational strategy.

Furthermore, within research in the field of teacher training, it is well-known that the experiences that teachers had as students has a strong influence on their teaching practice (Gil et al., 2000). This becomes an obstacle for change, and overcoming it is not easy. The literature also reveals that it is not enough to just produce new educational materials, offer more training courses or present research results to in-service teachers to promote changes in their practice. Instead, considering the influence of pre-service experience on current practice is highlighted as necessary. Buck (2009) suggests giving more importance to formative assessment and effective feedback on teaching practice.

For that reason, the class on *Teaching Science* tries to offer training models consistent with the type of scientific education that we seek to promote in primary schools. This research was designed within this context. Taking as a reference the work by Márquez et al. (2006) on natural water circulation, the urban water cycle perspective has been incorporated into the teaching sequence designed to promote self-regulation and learning (Sanmartí, 2007).

The objectives of this research are:

1. To analyze changes in participants' understanding of the water cycle when the research results are integrated into the class on Teaching Science.
2. To detect what implications emerged through a reflection on a learning process that includes the research results.

METHOD

To guide the teaching process, different activities (Figure 1) were scheduled. Data were collected at the beginning, middle and at the end of the process using different tools.

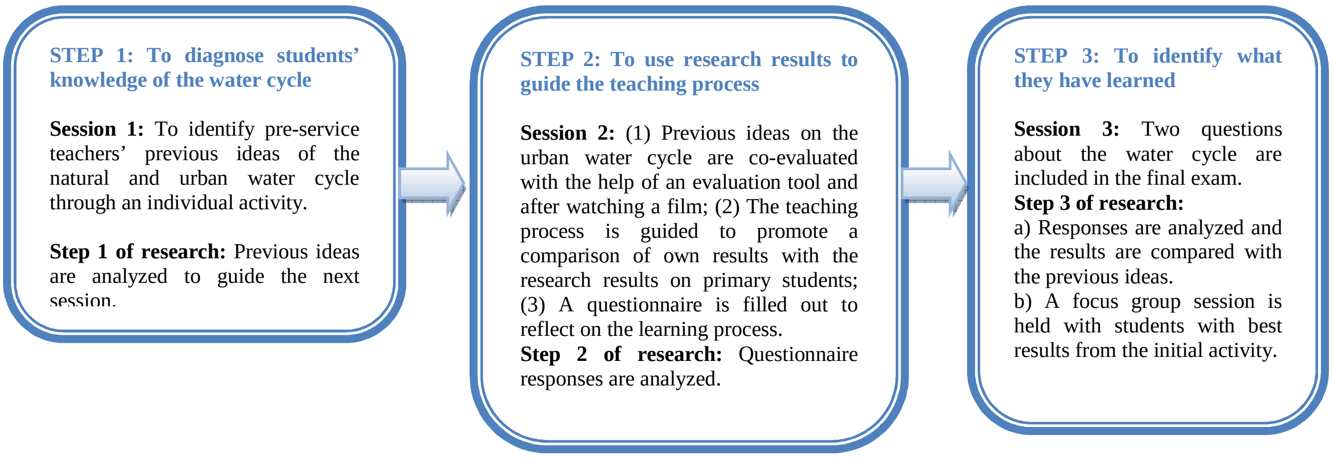

Figure 1: Sequence of activities, data collection and data analysis process

In the first session (step 1 of Figure 1), pre-service students did an individual activity to identify their prior ideas about the natural and urban water cycle (Figure 2). All results were collected in order to analyze their representations of the urban water cycle. The results provided an accurate understanding of students' prior ideas on the water cycle and were used to guide the teaching process in the next session.

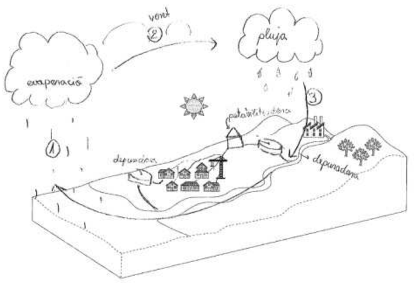

Figure 2: Students' initial representation of the water and urban water cycle

In the second session (step 2 of Figure 1), the students watched a film on the urban water cycle and later co-evaluated their output on the urban water cycle using an evaluation criteria tool. After this activity, the researchers gave feedback on the results of the group’s knowledge of the urban water cycle and compared them with the results of primary students. At the end of the session, the students filled out a questionnaire in order to collect their reflections on the learning process (Figure 3).

Figure 3: Activities during the second session

Finally, to detect learning improvements regarding the urban water cycle, two questions about it were included in the final exam (Figure 1, step 3). This data was also analyzed.

At the end of the process, we held a focus group discussion with the students that had the best results. One of the aims of the session was to detect the school experiences which helped them to build the cycle model. However, the focus group session also increased the student teachers’ level of interest in dealing with water issues from a scientific and environmental perspective.

RESULTS

Evolution in students’ learning on the natural and urban water cycle

In the initial activity (step 1 of Figure 1), students represented their prior ideas about the water cycle through a drawing. In the case of the natural water cycle, the data were analyzed with reference to the categories defined by Marquez (2002). In the case of the urban water cycle, the data were analyzed with a set of categories used in a previous research.

Table 1

Natural water cycle typologies

Typologies (Márquez, 2002)		**No. Students**
Type 0	No description	0
Type I: ***Monocyclic model***	Inputs and outputs not closed	3
Type II: ***Atmospheric model***	Cycle starts at sea, water evaporates, forms clouds, rains over sea	13
Type III: ***Surface circulation model***	Sea, river and lake water evaporates, forms clouds, rains over surface, and rivers formed flow into sea	33
Type IV: ***Groundwater flow model***	Like Type II, plus groundwater circulation, but no infiltration process	4
Type V: ***Groundwater flow model as independent reserve***	Infiltration process may be displayed, but not how water rejoins cycle	2
Type VI: ***Integrative model***	Shows infiltration process: surface water becomes groundwater and reaches sea	4

Table 2

Urban water cycle typologies

Typologies (Castelltort & Sanmartí, 2013)		No. Students
Type 0	No description	0
Type I: ***Transport or treatment***	Description of water transport system *or* water treatment	11
Type II: ***Incomplete transport and treatment***	Incomplete description of water transport system *or* water treatment	30
Type III: ***Transport and treatment differentiation***	Description of water transport system and water treatment; differentiation between purification and depuration	1
Type IV: ***Purification, transport and sanitation system***	Description of purification process, water transport system and sanitation system (sewers and depuration)	18
Type V: ***Provision and sanitation system***	Description of provision system (purification, transport, storage, energy requirements, and sanitation system)	0

The results showed that most of the students described a closed **natural cycle** but only few of them described groundwater and its circulation (Table 1). In the study carried out in primary schools, these difficulties were also detected among an even larger number of pupils.

In case of the **urban water cycle** (Table 2)**,** the results showed that all the students were capable of describing the cycle, although the majority did not yet have a sufficiently clear picture of the main processes and fell within type 2. None of the students described a complete system which includes the water supply (water treatment, transportation, storage and distribution) and water sanitation processes while also considering the energy requirements of the process.

At the end of the course, the students took a final exam (step 3 of Figure 1). In the exam question, they were shown a real representation of the water cycle made by primary school students. They had to do two tasks: to develop a list of evaluation criteria and to evaluate the representation using the defined categories. They had the option of choosing between developing criteria and an evaluation for either the natural water cycle or the urban water cycle. Nearly half of the class (31 students) chose the urban water cycle.

To detect learning improvements, we compared the results of the initial activity with the final exam activity using the same evaluation criteria. Frequencies for each item were analyzed. We also analyzed items in which they had improved remained the same or worsened on the final exam. This dual way of analyzing the data provided important information for interpretation.

By comparing the typology of the urban cycle identified in the initial drawing with the final exam, we found that the students improved considerably (*Figure 4*). However, the analysis of each criterion shows which aspects they improved and which they did not (*Table 3)*. The results show that on the final exam most of the students improved by including the purification and sanitation system and the energy requirements of the urban water cycle. However, they did not improve by including water point collection and the importance of representing a closed water cycle. The issues in which obvious improvements were not sufficiently noticed can be explained by the following factors: (1) some concepts were not sufficiently explicit in the co-evaluation criteria, and (2) the initial and final activities were not exactly the same.

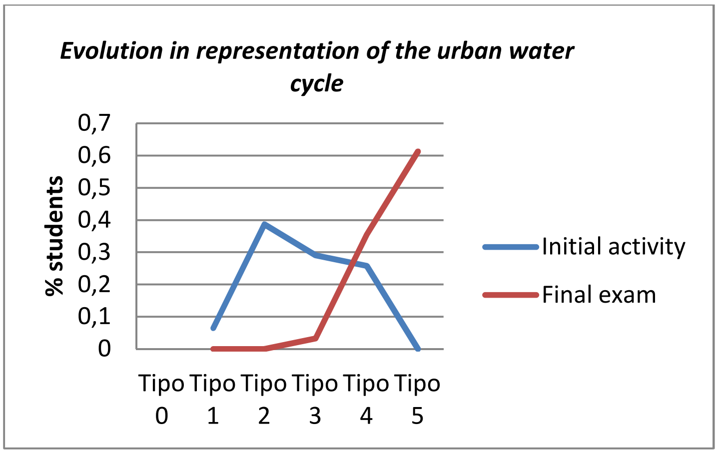

Figure 4*: Evolution in typologies of representations of the urban water cycle*

Table 3

Evolution in students' learning results

Items evaluated to identify student learning	**Initial activity (step 1)**	**Exam activity (step 3)**
Distinction between purification and the sanitation system	7	30
Identification of energy requirements	1	19
Representation of storage	3	8
Detailed representation of water transport	1	12
Representation of water collection point	21	13
Representation of a closed water cycle	28	25

Green: Ideas that most students improved
Orange: Ideas that only some students improved.
Red: Ideas where we did not detect any improvement.

Meta-reflection on the learning process

The reflection on the learning process took place at the end of the second session *(step 2 of Figure 1)* and with the focus group held at the end of the process *(step 3 of Figure 1).*

In the second session, the results of water cycle knowledge in the pre-service student group were presented and compared with the results obtained among the primary school students. After that presentation, two questions were answered individually (Table 4).

Table 4

Questions to promote individual meta-reflection

1. What have you learned about the natural and urban water cycles with this activity?
2. If you were a teacher, what kind of activities you think would be the most suitable for a group of primary school students?

The first question asked what they had learned. Although the question was very open-ended, we collected a wide range of responses (*Table 5*). The results show that all students learned something new with the sequence of activities planned. They claimed that they learned new scientific contents (both the natural and urban water cycle) and they put their scientific ideas in order. But they also claimed learning related to their future jobs as teachers, such as the importance of lifelong learning and the importance of educational research to learn preconceptions and students' difficulties in order to develop the teaching process better.

Table 5

Meta-reflection on the learning process results

What did you learn about the natural and urban water cycles with this activity?	
% students	**Responses**
46%	They learned about the natural water cycle
84%	They learned about the urban water cycle
23%	They learned about the water cycle in general (put ideas in order, complexity of water cycle and relationship between parts...)
44%	They learned about their future teaching tasks (importance of lifelong learning, importance of preconceptions, new resources, primary students' main difficulties...)
25%	The activity helped them learn

The second question asked about their teaching practice in order to find out which strategies they considered to be the most appropriate ways of tackling the difficulties encountered with these pupils. The ideas collected were based on using and encouraging activities and resources in a variety of formats to create educational experiences that help students to identify their preconceptions, and to regulate and evaluate them so they evolve. These suggestions are all consistent with general primary pre-service teacher training and teaching science subjects.

At the focus group session, students were asked about the kind of school experiences they thought that had helped their learning. The experiences collected were related to not only formal education but also non-formal education and the professional and personal spheres. In the case of formal education, students highlighted the importance of *outdoor activities* (such as visiting water sources in a natural setting, visiting a water museum, a river outing, etc.) and *research activities* (such as eco audits, water bill analysis, calculating one town's water balance, etc.).

The value of these experiences has been described by many authors (Rickinson et al., 2004; Chawla, 2006), and we have also reached the same results in a study carried out with primary schools. In that research, we were able to identify several characteristics that helped primary students to learn: the activities had an adequate teaching design, the activities provided students with a unique or different experience, and teachers used these activities in coordination with their teaching plan.

Furthermore, the focus session was also useful to reflect on the sequence of activities planned. In the conversation, some of the ideas collected through the questionnaire were also explained (Table 6):

Table 6

Some examples of focus group comments about the activities planned and their learning

Student A: "If we want children to learn, we must have a clear picture of their difficulties". *Student B: "I agree, but we also have to be aware of our own difficulties. I was so surprised to see that many of us didn't represent the water cycle correctly. We are going to be teachers and we must have basic scientific knowledge. We have to be conscious of our knowledge in order to improve it".* *Student C: "…and that these kinds of projects* [research] are *useful."* *Student D: "It helps us very much to know where we are."* *Student E: "These kinds of studies are very necessary and more of them should be done. That is more important than other studies like the ones that tell you what kind of perfume people prefer."* *Student H: "We have to know that lifelong learning is very important"*

The responses of the questionnaire and the focus group show the importance of allocating time for meta-reflection. It was useful for students so they could become more conscious of their difficulties and better able to identify strategies to overcome them. Being aware of these difficulties also means that they realized that their own problems were very similar to those of primary pupils. This encouraged wider reflection on learning that includes both content and teaching practice. However, we cannot know whether they are going to apply what they have written or said in their future teaching practice.

CONCLUSIONS

The results of this research have shown that a teaching sequence that integrates scientific content, research results, self-regulation and meta-reflection has an effective impact on learning. Students learned both at a conceptual level and with regard to their future teaching.

Related to the first research objective, by the end of the process all the students had improved their understanding of the urban water cycle. For example, they made a distinction between purification and sanitation systems, and most of them identified the energy requirements of the process.

Related to the second objective, the meta-reflection during the teaching process encouraged student learning with regard to their future teaching tasks. The focus group discussion was a useful place to think more deeply about the implications of a learning process that includes the research results. The implications that emerged were consistent with the implications collected through the questionnaire. They include the importance of lifelong learning to improve scientific knowledge in order to be able to help student learning; the use of more adequate didactic strategies; and realising the importance of research into teaching.

In addition to those results, the focus group session became an approach to significant formative life experiences which students said helped them to learn about the water cycle. Events of high importance produce more vivid and accurate memories than events of low importance (Chawla, 2006). Outdoor learning and research activities are two events regarded as important.

The literature suggests that even if students remember fieldwork or outdoor visits for many years, it does not always mean that they were effective learning experiences (Rickinson et al., 2004; Dillon et al., 2006). In our research carried out with primary schools, we have evidence that this kind of experience allows for better understanding of the urban water cycle. This data is important because the socioeconomic situation in our country has led many schools and institutions that offer this kind of outdoor educational visits to reconsider whether outdoor learning is worthwhile.

To summarize, the experience of establishing links between teacher education and research carried out in university departments has been very positive for both the student teachers and the researcher. The student teachers have learned more about water issues and have seen how research helps teachers to identify pupils' difficulties and potentialities and identify improved activities in order to adjust preconceived ideas. The researcher was also able to collect new data on the difficulties encountered by prospective teachers and to identify school experiences that have been helpful.

Acknowledgements

Based on work supported by Spanish MCYT grant EDU-2009-13890-C02-02, Spanish MCYT grant EDU-2012-38022-C02-02 and Catalan PRI 2009SGR1543.

REFERENCES

Bar, V. (1989). Children's views about the water cycle. *Science Education*, 73(4), 481-500.

Buck, G. A. & Trauth-Nare, A. E. (2009). Preparing teachers to make the formative assessment process integral to science teaching and learning. *Journal of Science Teacher Education*, *20*(5), 475-494.

Castelltort, A.; Sanmartí, N. (2013). El aprendizaje interrelacionado de contenidos de ciencias y actitudes ambientales en la Educación Primaria. *Revista Enseñanza de las Ciencias*, special issue, 726-731.

Chawla, L. (2006). Research methods to investigate significant life experiences: Review and recommendations: Reprinted from Environmental Education Research (1998) 4 (4), pp. 383–397. *Environmental Education Research*, 12(3-4), 359-374.

Dillon, J., Rickinson, M., Teamey, K., Morris, M., Choi, M. Y., Sanders, D., & Benefield, P. (2006). The value of outdoor learning: Evidence from research in the UK and elsewhere. *School Science Review*, 87(320), 107.

Gayford, C. (2002). Environmental literacy: Towards a shared understanding for science teachers. *Research in Science and Technological Education, 20* (1), 99-110.

Gil, D. & de Carvalho, A. M. P. (2000). Dificultades para la incorporación a la enseñanza de los hallazgos de la investigación e innovación en didáctica de las ciencias. *Educación Química*, 11(2), 250-257.

Gunckel, K. L., Covitt, B. A., Salinas, I., & Anderson, C. W. (2012). A learning progression for water in socio-ecological systems. *Journal of Research in Science Teaching*, 49(7), 843-868.

Lemke, J. L. (2006). Investigar para el futuro de la educación científica: Nuevas formas de aprender, nuevas formas de vivir. *Enseñanza de las Ciencias, 24* (1), 5-12.

Littledyke, M. (2008). Science education for environmental awareness: Approaches to integrating cognitive and affective domains. *Environmental Education Research, 14*(1), 17.

Márquez, C. (2002). *La comunicació multimodal en l'ensenyament del cicle de l'aigua*. Bellaterra: Universitat Autònoma de Barcelona.

Márquez, C., Izquierdo, M., & Espinet, M. (2006). Multimodal science teachers' discourse in modeling the water cycle. *Science Education*, *90*(2), 202-226.

Poch, M. (1999). *Las calidades del agua*. Barcelona: Rubes.

Rickinson, M.; Dillon, J.; Teamey, K.; Morris, M.; Choi, Y.M.; Sanders, D.; Benefiled, P. (2004). *A Review of Research on Outdoor Learning*. Preston Montford, Shropshire: Filed Studies Council.

Sanmartí, N. (2007). *Evaluar para aprender: 10 ideas clave*. Graó.

Sanmartí, N., Burgoa, B., & Nuño, T. (2011). ¿Por qué el alumnado tiene dificultad para utilizar sus conocimientos científicos escolares en situaciones cotidianas? *Alambique, didáctica de las Ciencias Experimentales, 67*, 62-69.

Sauvé, L. (2010). Educación científica y educación ambiental: un cruce fecundo. *Enseñanza de las ciencias,* 28(1), 5-18.

Simonneaux, J., & Simonneaux, L. (2012). Educational configurations for teaching environmental socioscientific issues within the perspective of sustainability. *Research in Science Education*, 42(1), 75-94.

Shepardson, D. P., Wee, B., Priddy, M., Schellenberger, L., & Harbor, J. (2009). Water Transformation and Storage in the Mountains and at the Coast: Midwest students' disconnected conceptions of the hydrologic cycle. *International Journal of Science Education*, 31(11), 1447-1471.

Taiwo, A. A., Ray, H., Motswiri, M. J., & Masene, R. (1999). Perceptions of the water cycle among primary school children in Botswana. *International Journal of Science Education*, 21(4), 413-429.