Chapter II

Social and Constructivist Learning Theories in the Context of Educational use of Virtual Instrumentation

II.1. What is Science effective teaching and learning?

In order to define teaching and learning effectiveness, two terms are worth mentioning: **intention and achievement**. **Effective teaching means the capability to achieve goals**. Independent from a specific school subject, field literature argues that developing and improving the teacher's effectiveness should be based on the following fields:

1. *Theoretical knowledge of human behavior and ways of learning.*
2. *Developing attitudes making learning easier as well as enabling to form good relationships with others.*
3. *Profound knowledge of the subject taught.*
4. *Mastering teaching techniques making students' learning easier.*

Another aspect is the practical use of the above competences, i.e. adopting teaching styles. There are two contradictory teaching styles: directive and non-directive. The former one is considered more effective, but a reasonable mixture of both styles may also bring about good results. The research points at several attitudes and behavior characteristic of an effectively working teacher. Such a person should be warm (kind-hearted) and understanding, enthusiastic and zealous, accepting students' emotions and feelings, motivating them with prizes, supporting them in overcoming difficulties. In the classroom management the important aspects are: clearly stated goals and teaching content, putting forward questions, inspiring students' imagination, enabling them to work autonomously, using various teaching methods, techniques and materials.

Taking decisions is the key task to be undertaken by an effective teacher. They refer to three stages of teaching: planning, teaching, evaluating. Each of them requires specific skills. E. Perrot gives their following characteristics:

- *for planning – diagnosis of students' needs, stating general and specific goals, deciding which activities are the most adequate to achieve the goals;*
- *for teaching – the easiness with which the teaching material is presented, explaining, listening, introducing new material, demonstrating, eliciting responses, winding up and summing up discussions*
- *for evaluating – stating teaching goals that are to be evaluated, discriminating information that is to be evaluated, getting the information, putting it down and giving opinion.*

Today's Science teaching in Europe is marked by the social and human constructivist as well socio-cultural ideas. The curriculum favors approaches that demand active participation, intensive interaction, and thoughtful reflection. These activities may take the form of small, cooperative group work, debates, one-on-one conversations, demonstrations, or laboratories that introduce and attempt to resolve conceptual conflict. Also interactive technologies are used as well as whole-class activities that provide context and encourage meaning-making, such as historical vignettes and the creative use of analogies, metaphors, and story-telling.

Learning by doing entails transition from the level of concrete activities through illustrative to abstract ones, which means carrying out manual operations (building, cutting out etc.), then drawing and interpreting pictures and schemes, and finally, conducting the reasoning through figures, symbols etc. This way, the level of intellectual development of students is taken into consideration as well the natural sequence of concepts acquisition from the concrete to abstract ones. Using this model allows, to a greater extent, for taking into account students' already acquired experience, which helps to comprehend new concepts and enhances their motivation.

Apart from the relevance of learning through action, the experience gained in *VccSSe* shown the participating countries that effective Science teaching means training students in use of disciplinary and transversal information processing skills. Thus, students need to learn how to learn. The use of concept maps and other metacognitive strategies can help students to monitor and control their own learning. The assessment strategies like multiple-choice/true-false, fill-in and similar "objective" tests are discouraged and concept maps, essays, portfolios, verbal reports, and other methods that recognize, reward, and encourage meaningful learning are favored.

Skills can be fostered in different ways. Three categories of components of critical thinking can be pointed: meta-components (higher order mental processes used in plan, monitor, and evaluate what the individual is doing), performance components (the actual steps the individual takes), and knowledge-acquisition components (processes used to relate old material to new material and to apply new material). Critical thinkers tend to be open minded, take a position when the evidence calls for it, take into account the entire situation, seek information, seek precision in information, deal in an orderly manner with parts of a complex whole, look for options, search for reasons, seek a clear statement of the issue, keep the original problem in mind, use credible sources, remain relevant to the point, and be sensitive to the feelings and knowledge level of others. The best way to teach thoughts is to ask students to explain their thinking, to require them to support their answers with evidence, and to ask them thought-provoking questions.

Scientific curricula must also include an understanding of the overall set of equipment and procedures, both technical and technological, of everyday domestic, social and professional life.

Science and teaching are social processes dependent on attitudes, values, and social interests, not just on knowledge and skills. Scientists transform their observations into findings through argumentation and persuasion, not through measurement and discovery. The classroom discourse can be organized around student argumentation that brings into focus an alternative view of science and science education as socially and culturally constituted, meaning-making. Classroom activities in which students learn through design, invention, and construction model scientific work and thus help to understand the nature of science.

In the view of Spanish science teachers and experts, the knowledge of Physics, chemistry, mathematics and biology, incorporated into culture as a technological tool, has become essential to the development of contemporary citizenship. It is expected that the teaching of Scientific subjects at the Secondary educational level will contribute to develop an effective scientific culture that will, in turn, allow individuals to interpret natural events, phenomena and processes, thus situating and scoping the interaction between human beings and nature as part of a constantly changing Nature.

Using virtual simulations and experiments meets most of the requirements of effective teaching. Mostly, it allows not only for more students' autonomy but also for making exercises and tasks more attractive and differentiating the difficulty levels of the tasks.

II.2. Socio-constructivist Principles and Effective learning

Cognitive theories take the perspective that students actively process information and learning takes place through the efforts of the student as they organize, store and find relationships between information, linking new to old knowledge, schema and scripts.

Constructivism considers learning to be an individual and personal event. It argues that people construct, reconstruct and deconstruct their own understanding and knowledge of the world through experiencing things and reflecting on those experiences. For this, they must ask questions, explore and assess what they know. The following principles are based on the work of various constructivist theorists and are offered as a framework for this discussion.

• **Learners bring unique prior knowledge, experience, and beliefs to a learning situation**. Every learner has experiences that influence his or her understanding of the world. Those unique experiences are the foundation for learning; they provide opportunities for personal connections with new content.

• **Learning is internally controlled and mediated**. Learners take in information, process it to fit their personal frameworks, and build new understanding. That knowledge construction occurs internally, in the private domain of each individual.

• **Knowledge is constructed in multiple ways, through a variety of tools, resources, experiences, and contexts**. Constructivist learning theory tells us that we learn in a variety of ways. The more opportunities we have, and the more actively engaged we are, the richer our understanding. Good teachers have always used experience as a valuable instructional tool; that is why we arrange field trips and hands-on projects. It is why an internship or apprenticeship is essential to the completion of most vocations, including teaching.

• **Learning is a process of accommodation, assimilation, or rejection to construct new conceptual structures, meaningful representations, or new mental models**. Every person is surrounded by an infinite variety of images, ideas, information, and other stimuli that provide raw material for thought and understanding.

If new information matches the learner's existing understanding, it is easily assimilated. If it does not match, the learner must determine how to accommodate it, either by forming new understanding, or rejecting the information.

• **Learning is both an active and reflective process**. Learners combine experience (action) and thought (reflection) to build meaning. Both parts must be present to support the creation of new knowledge.

• **Social interaction introduces multiple perspectives through reflection, collaboration, negotiation, and shared meaning**. In many situations, learning is enhanced by verbal representation of thoughts - it helps to speak about an idea, to clarify procedures, or float a theory to an audience. The exchange of different perceptions between learners enriches an individual's insight.

A major idea in social constructivism approach is that learning is affected by social interaction. Discussions, conversations, explanations, listening - all these are ways we learn by interacting with others. Encouraging social interaction among students is not common in classrooms - even classrooms of excellent teachers. If social intercourse is, indeed, an essential part of learning, our students need more opportunities for discussion to develop their understanding.

During the past decade there has been a growing interest towards socio-cultural approaches in learning sciences. The socio-cultural framework appears to give appropriate tools for observing and conceptualizing the emerging forms of practices and work of our times, such as collaborative work in groups, distributed expertise and networked activities. Instead of studying the mental content of individual minds, the various approaches of this framework focus on interaction, discourse and participation processes. Individuals' thinking is mediated through the cultural symbol systems and artifacts we use.

The fact that an individual should be involved in the solution of empirical problems is considered to be an essential factor in his construction of knowledge according to modern constructivist and social theories of learning. In this regard, the value of their cognitive structures is determined by how much these tarry with their experience and the extent to which they are viable; that is to say, the extent to which they can be used to resolve problems. Knowledge construction through experience consists of the possibility of discovering the basic elements useful to avoid or repeat. In order for it to be possible for the individual to learn through their experience, it is to be supposed that they can observe and organize their experience as well as separate it into parts, the classification of which is to be performed by selecting certain criteria concerning the similarities and differences of these parts. Subsequently, it is necessary to interpret the said experience in light of the expected results in future similar situations. If, through this organization of experience, a conclusion is drawn that appears to be useful, this means that the organization is viable, could not be done in any other way and that the individual has comprehended something from the real world. The organization of experience so as to allow the formulation of valid forecasts means comprehension according to the constructivist perspective of knowledge construction. Thus, the truth of knowledge does not depend on the extent to which it expresses a reality

In the context of classroom use of Virtual Instrumentation tools (Vis), students can experiment and realize a geometrical or physical construction but also be intrigued by what can happen in a problem by formulating hypotheses, conjectures and generalizations. The formulation of these proposals can be supported by the empiric data displayed on the computer screen. The possibility of visualization on the computer screen of infinite states of a figure that belong in the same class of constructions (the criterion being their certain attributes) gives students the opportunity to formulate specific conjectures for these attributes supported by empirical data. Through this kind of experimentation, students can acquire certainty about their hypotheses and the desire to find ways to prove them.

II.2.1. The Importance of a Student's Actions in His/Her Learning by using VIs.

Science knowledge should not be considered limited to the possibility of retraction of information from some storage space such as the memory of individual but connected with the possibility of producing new results. What is considered new is surely dependent on the person who realizes it. For example, something constructed for the first time by a student is probably not new to their professor. From this point of view, importance should be placed on the actual process of knowledge acquisition and not only on the results of this process. The first appearance of functional thought comes through the actions of the individual to achieve specific aims integrated within the context of meaningful activities. These actions are followed by certain simple abstractive operations that arise from the objects used in combination with an abstractive operation that emanates from the reflection of individual on their actions. During this process, an individual's cognitive operations are created. In fact, these operations constitute actions that have been internalized by the individual. These operations are reversible and have something immutable.

The Virtual Instruments we tested during the project (*Cabri Geometry II*, *Crocodile Clips*, *LabVIEW*, *GeoGebra*) do not present students with knowledge in the form of text-based information. In fact, they allocate basic scientific tools and operations that students can use both alone and in combination in order to actively construct their knowledge. Students' constructions are influenced by the type of tools used.

Thus these tools offer a highly interactive environment, since most student actions are accompanied by meaningful feedback - visual and numerical - as well as text-based messages so that they do not feel lost in the environment. These possibilities can provide students with capabilities for "active" learning in contrast to traditionally inactive environments, such as the paper-pencil environment and other environments where natural objects are used. In fact, a student can realize actions in inactive environments but they are not connected with certain results and are also distanced from their actual scientific meanings. The exploitation of the auto-expressive features of computers allows for the connection of visual science information with symbolic information.

II.2.2. The Importance of Reflection in the Learning of the Individual and the Role of the Feedback Provided by VIs

Functional knowledge is the result of reflection. Despite the fact that reflection itself cannot be observed, its function does have observable results. Reflection is the ability of the mind to observe operations. It is a preliminary stage of the interpretive process for a situation and is constituted by experiences. The interpretive process aims at helping the individual to answer questions such as what has happened and why. Answering these questions pre-supposes the formation of various hypotheses and selection among them of the most appropriate. To this end, reflection on the categories formed using a significant amount of experiences is significant. Reflection is necessary not only for students but also for teachers if they are to consider and make appropriate interventions in their teaching sessions.

The reflection process requires effort, because science learning often requires multiple layers of abstractive activities. In turn, successful effort in reflection requires powerful motivation, such as that emanating from the internal satisfaction of the student, that which is obviously unrelated to the external rewards given by their teachers.

Visual feedback on student actions constitutes a very powerful learning tool, since it helps students to reflect and be aware of their experience and consequently enable them to control their actions. The computer is perhaps unique in the sense that it allows the student to produce various graphical representations of scientific phenomena and see the results when these representations are directly manipulated and transformed into more sophisticated constructions. The visual feedback which accompanies almost every action performed by the students in the context of *Cabri Geometry II*, *Crocodile Clips*, *LabVIEW* or *GeoGebra* can be seen as an efficient way of visually communicating their science ideas, an important aspect of effective science learning as declared by the field literature.

II.2.3. The Role of Tools in Student Intellectual Development and the Tools Provided by tested virtual instruments.

The importance of psychological tools in the modification of human behavior has been **likened** to the effect of tools in the modification of human labor (Vygotsky, 1978). By psychological tools, we mean semiotic systems such as oral and written language, the systems of numeration and the representation systems in general.

Lev Vygotsky places the source of a child's higher mental functions in the inter-psychological space of cultural effect. He considers that a culture does not create but simply modifies natural data as a result of the internalization of socio-cultural experience. According to Vygotsky a child's higher mental functions evolve from the interpersonal to a personal level through the process of internalization.

Vygotsky (1978) introduces signs into the social life of persons and their interpersonal interactions. The introduction of signs and symbols and their use as mediators of socio-cultural participation provide teachers with productive ways to comprehend the **meaning** of imitation, action, gesture and their effect in knowledge construction. Moreover, it allows the possibility to face teaching as a product of social negotiation of different points of view (Steffe, 1990). It also provides an interesting context for computers, which are as much tools as hammers and scissors, but which can also represent symbolic systems and consequently carry psychological signs (Noss and Hoyles, 1996) and therefore be viewed as mediators of socio-cultural participation in the process of learning.

As regards the role of tools in terms of developing students' knowledge, it is reported that "the use of tools is central for the student in the process of mathematization of his activity" (Cobb, 1997; pp. 170). The availability of various tools and representation systems provides opportunities for individualized learning, because it allows each student to work according to their needs. The availability of tools can also help students to form hypotheses and justifications as well as generalizations and conclusions. Furthermore, tools can mediate between the student and the scientific meanings constructed in the context of a science teaching activity. In particular, it is reported that:

- Tools constitute devices to access the knowledge of other individuals;
- The comprehension of a concept is connected with the type of tools used;
- Tools do not simply serve the intellectual activities but also shape and modify them;
- Tools mediate and are a decisive influence on the actions of the learner;
- The learning activity, the tools and the learner's actions are interconnected in unique ways in each specific learning case.

The effect of different tools on the ways used by students to realize specific learning activities have been reported (Laborde, 1993). Noss and Hoyles (1992) report that the tools are not independent from the learning context in which they are integrated and consequently students are not totally free in their choice but influenced by this context.

For finishing with an example, *Cabri Geometry II* allocates a variety of tools for the realization of various geometrical constructions, tools which have been designed to display geometrical concepts graphically on the computer screen. Moreover, the shapes which are produced and displayed are computational objects, which mean that their attributes are conserved while their visual figures are altered through direct manipulation. On the whole, the tools provided by *Cabri* and the geometrical constructions formed using these tools play the role of mediators between the geometrical concepts which they embody and the student during her/his interactions within the program.

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