2. Part A – Theoretical Framework

This research wishes to promote the development of professional science teaching practice inside and outside the classroom through the formation of an international learning community of botanic gardens and natural history museums.' Cultural psychology design based research' (Bell, 2004) is applied to better understand how to orchestrate innovative learning experiences amongst a network of socio-cultural diverse organisations. The research focus is put the local social world to understand

> 'how imposed theoretical views are interpreted by the participants, opening up the possibility that new theoretical insights can be gleaned about where projected theory falls short through systematic, emic examination of the participants engagement in the intervention'(ibid, p. 249)

Thus the following pages are dedicated to provide an insight into the complex 'theoretical views' that informed the INQUIRE project design and its implementation and thus account for its progression.

Let's get started with two very basic concepts, 'Science' and 'Science Learning'. Both seem to be very simple and commonly used terms. However, as soon as we look more closely at them and reflect on the science education literature, these two terms are not as easy to envisage as one thinks and are a matter of a long-lasting discourse among science educators. It is entirely possible that even each reader of this work may hold an individual perspective. The literature about attempts to define either of these two aforementioned terms is vast. However, the purpose of this paper is not to provide

How to cite this book chapter:
Kapelari, S. 2015. Theoretical Framework. In: Kapelari, S *Garden Learning: A Study on European Botanic Gardens' Collaborative Learning Processes*, Pp. 9–99. London: Ubiquity Press. DOI: http://dx.doi.org/10.5334/bas.b. License: CC-BY 4.0.

a synopsis of the literature on the Nature of Science or the Nature of Science Learning as that has been done elsewhere (e.g. Hohenstein & Manning, 2010, Lederman & Lederman 2012, Bransford et al., 2000) but to raise awareness about the fact that different perceptions of these concepts are omnipresent in science education.

2.1 What is Science?

When I talk about science I am mainly referring to the natural sciences, Biology in particular, and I refer to science as a particular approach to making sense of the world around us. Asking the question 'what is science?' implies there will be a definitive answer, however Science refers to a substantial breadth of human knowledge and endeavor and the boundaries of science are not clearly defined.

Science is both a body of knowledge that may be seen as a collection of isolated facts, and a process of discovery which links isolated facts into a coherent understanding of the world around us. Modern science was established as a social institution in Western Europe in the 17th Century and was accepted in the academic society in the 19th century (Thorlindsson & Vilhjalmsson 2003). There is not one interpretation of science, or one single way of applying science, or classifying a work as being scientific. The term science is an abstraction summarising multiple approaches to gaining knowledge.

With flowers, there is a great variety of different shapes and colours. Some flowers are easily recognised as being flowers and others may only be detected by a specialist's eye. However it is commonly agreed that there is a particular structure that enables us to recognise an organism as a flower and that helps us to communicate confidently and accurately about flowers. Although the term 'flower' is used commonly by the lay person, for example in a florist, it may often be used incorrectly (according to the scientific definition) for example referring to flowering heads made up of many flowers and even a whole plant with stem, leaves and flowers! It is only when we observe closely and with understanding of a flower structure that we can see the 'real flowers' and observe their different characteristics. Thus individual people's understanding and use of the term 'flower' is often very different.

In the same way, people in the science researcher's community share a common understanding of science patterns although there will also be many different perspectives when we look at domain specific aspects in more detail. As with the term 'Flower' there are macro patterns we commonly share and micro patterns we still have to define and argue about - whether they are, should or should not be included to the currently accepted concept of 'Science' (Bechtel, 1988). Discussions on these 'micro patterns', though fascinating, are not the purpose of this paper and should be a matter for science philosophers. However it is important to be aware about it because these micro patterns do influence people's perception of science inquiry and the nature of science.

Lederman and Lederman (2012) argue that to answer the question "What is science" the one valid answer delineates science into:

1. The Nature of Science Knowledge
2. The Body of Scientific Knowledge
3. The Variety of Science Process/Method

2.1.1 Nature of Knowledge?

Metaphors are central not only in young people's science learning but in scientific thoughts, discourse and practice in general. Teachers and scientist use them to explain theories and their work and they can make visual concepts a person or group hold (Lakoff & Johnson, 1980).

Ann Sfard (1998) proposed two metaphors to think about knowledge creation. The most broadly accepted one is sometimes known as "folk theory of mind and learning" and sees knowledge as a property of each individual's mind. Knowledge can be collected and accumulated in a kind of container and learning is the process the individual mind follows to fill this container. It is a matter of construction, acquisition and outcomes, which becomes visible in the process of using and applying this knowledge in new situations. This metaphor is properly known as the *acquisition metaphor* and is held in contrast to the *participation metaphor*, which sees knowledge as a process of participation in various cultural practices and shared learning activities.

In the latter the focus is more on activities (knowing) than on outcomes (knowledge). Knowledge in this metaphor is seen as an aspect of cultural practices. Knowledge is distributed not only between individuals but also over their environment. Learning is situated in these networks of distributed activities. Knowledge and knowing cannot be separated from situations where they are used or where they take place. Therefore knowledge is a matter of enculturation and learning is situated in this culture. Discourse, interaction, activity and participation supplement, or sometimes even replace the terms acquiring and accumulating knowledge (Paavola et al., 2004).

The debate between cognitive and situated perspectives of learning is nourished by these two metaphors. Sfard (1998), along with a couple of others, had already concluded at the end of the last century that both perspectives are needed and that they are not 'rivals' but complement each other (Paavola et al., 2004). Bereiter´s (2002) concept of *knowledge building* argues that the emergence of the knowledge society has given rise to a view of knowledge as a thing that can be systematically produced and shared among members of a community. This infers that therefore knowledge follows a building process that includes collective work in order to produce conceptual artefacts. These artefacts may, or may not, be of practical use (eg. new technology or theories and ideas).

> 'This model makes a conceptual distinction between learning, which operates in the realm of mental states (in Popper's World 2), and knowledge building, which is generated by human minds whilst operating in a socially shared realm (Popper's World 3), which again makes use of material (World 1) objects for realisation.' (Batatia et al., 2012, p. 18)

For Paavola and colleagues (2004), scientific concepts can be seen as mediation between mind and matter.

Alongside, or even synonymously with, the discussion on metaphors of knowledge creation goes the discussion about metaphors for learning. In this respect there is no clear cut between these two metaphors. Rather

> '[. . .] the importance of these metaphors is that they present in concise form, typical and important main alternatives of understanding learning' (Paavola et al., 2004, p. 569)

Models of learning frequently combine aforementioned features in different ways and degrees. Paavola et al., 2004 conclude that although the term 'Constructivism' may become rather meaningless because it is used in many variations and interpretations, it can also be interpreted as an enhanced version of the acquisition metaphor in the sense that knowledge cannot be acquired directly but must be accumulated and constructed by the learner himself. In addition constructivism has affinities with the participation metaphor of knowledge creation, if the idea is that social and cultural practices are primarily constructed.

Engeström and Sannino (2010) argue that the 'Theory of Expansive Learning' (s. p. 31ff)

> 'does not fit into one of the two metaphors suggested by Sfard (1989). In fact, from the point of view of expansive learning both acquisition-based and participation-based approaches share much of the same conservative bias. Both have little to say about transformation and creation of culture [. . .] so the theory of expansive learning must rely on its own metaphor: expansion (p. 2).

Paavola and colleagues (2004) suggest a 'metaphor of knowledge creation' as a new and third one, while Fendwick add concepts such as participation, expansion and translation as relevant alternatives.

In terms of teaching practices our western Cartesian way of separating one from the other is keeping the discourse alive on whether teaching should focus either more dominantly on knowledge acquisition or on asking students to participate in cultural practices. Shared learning activities are still key focus for modern science education discussions.

To answer the question 'What is the nature of science knowledge' mentioned earlier, we may have to agree that generations of scientists have been gathering the knowledge we currently hold and future generations will naturally develop it further. Thus science knowledge is 'accumulated' as well as being a matter of 'participation' and 'expansion' in cultural practice (see below).

Sfard (1998) argues:

> 'After making the case for the plurality of metaphors, I have to show that this proposal is workable. Indeed, considering the fact that the two metaphors seem to be mutually exclusive, one may wonder how the suggested metaphorical crossbreeding could be possible at all' (p. 11).

2.1.2 The Body of Scientific Knowledge

The most fundamental principle in science is that scientists assume there is a world around us which does exist, which is real and can be observed and studied. Science is therefore the constructive process that humans apply to understand this world. It involves exploring natural phenomena, inventing new concepts and applying these new concepts to explain or interpret already known or new phenomena. *Knowledge* is produced and shared by a community which is united by agreed norms and social practices and is therefore socially and culturally situated. E.g. research findings are published, discussed and evaluated by peers of different nationalities. These social structures have been established over a long time already and are expanding constantly as well as successfully (Thorlindsson & Vilhjalmsson, 2003).

Scientific concepts are terms used to explain a particular phenomenon or object and they represent a knowledge content the scientific community currently shares e.g. when scientists talk about photosynthesis it is not just a term but the shared understanding of what we currently know about how plants collect an utilise sun energy. Scientists assume that by understanding single building blocks of a phenomenon and merging them together they will finally understand the bigger picture. Knowledge is accumulated and forms the scientific body of knowledge which is used to construct and reconstruct our understanding of the natural world (*acquisition metaphor*). Various concepts, laws, theories and ideas have remained unchanged for a long time now and are well represented in established specialist literature, peer reviewed journals and students textbooks. Scientists rely on this accumulated body of knowledge and work hard to establish the truth. However, it needs to be recognised that what is accepted knowledge today may change in the future. New or different perspectives and even contradicting knowledge could arise. This does not mean that anything produced by scientists is not trustworthy; a scientific concept that has been termed theory or law is the best understanding that we currently have. It has been tested and challenged, and questioned and tested again and to date it has not been proved wrong. However, there is always room for building on our knowledge and understanding, even for those commonly accepted theories or physical laws. There may still be aspects which have not been considered or a lack of technology that can offer an alternative perspective. There may also be an exceptional case not yet discovered.

2.1.3 The Science Processes and Methods

Lederman and Lederman (2012) summarized the characteristics of scientific inquiry as such: Scientific Inquiry extends beyond the mere development of process skills such as observing, inferring, classifying predicting measuring, questioning, interpreting and analysing data. Scientific inquiry includes the traditional science processes but also refers to the combining of these processes with scientific knowledge, scientific reasoning and critical thinking to develop scientific knowledge. The critical thinking aspect is particularly crucial in science. A skilled performance in scientific thinking cannot be separated from scientific knowledge eg. predicting or interpreting observations are very greatly depending on the context. Thus it makes it a huge challenge not only for students but for science teachers or science educators to engage in authentic inquiry. The contemporary view advocated for science inquiry is that the question guides the approach and the approach varies widely within and across scientific disciplines and fields. Thus no one single fixed set or sequence of steps is available which can be expected to cover all types of scientific investigations. Experimental design is often advocated as "the scientific method" but it is not representative of scientific investigations as a whole. Scientists rely on theory and create models to mimic the real world because this enables them to test predictions and explain puzzling observations. Thus science involves the invention of explanations which requires creativity in the sense of e.g. developing an experimental design or interpreting data.

One has to admit that scientists do not look at data without prejudice because observation is always filtered by existing preconceptions. Scientific knowledge is subjective. Therefore critical reasoning is applied. A scientific process does not only involve observations of the world only but scientists are required to use all their senses and ask causal questions. It includes recording accurate descriptions of what has been done and what has been observed as well as consideration of alternative ideas. Generating logical predictions along with planning and conducting reproducible experiments or observations are essential.

Data is collected to decide between competing explanations not to confirm already existing ones. Finally reasonable conclusions are provided and newly developed knowledge is disseminated. It is presented to the scientific community to be discussed, peer reviewed, challenged and questioned. Science therefore includes teamwork, as well as being a social process; not one single person can be blamed or acclaimed for what we know, or do not know or what we believe is correct or incorrect.

Although there is this scientific idea of gathering objective knowledge, scientists have to admit that not every single member or even whole groups of the scientific community may follow similar goals. There are always people who do not scrutinise competing explanations, but prefer to find or produce evidence for their own explanations. We find others who claim the stage of theory for a knowledge that has not been tested properly or is still subject of contradicting views. These people draw conclusions from weak evidence and try to hide this fact as it often helps them to further their careers or it improves their financial situation - however, that is human nature. It is important for those working in science research to address these issues openly and to support those teaching and learning science to be aware about it.

The concept of scientific literacy which will be addressed later is asking learners to develop knowledge and skills to distinguish between good and bad science. However, this is making high demands on lay persons and may not be realistic.

2.2 Selected Theories of Learning

Educational psychologist assume that learning theories and ideas relevant to education can provide important information for practitioners and thus need to be considered when designing, implementing and improving educational programs. However, general philosophical theories such as behaviourism, cognitivism, constructivism, humanism or socialism often fail to provide detailed guidance in organizing instructions (Weibell, 2012).

> ‘In the past decades learning theory has turned away from being an oversimplified general theory, and has evolved into a complex theory with several parameters that need to be specified for different real-world conditions. The idea that all kinds of learning processes in any situation can be accounted for by one limited general set of laws or mechanisms, has been replaced by a view on learning that acknowledges the importance of the *content* of learning, as well as the nature of the learning *situation*. Domain specificity and situatedness are now generally recognized as major parameters of any theory of learning. Context has become a hot issue in modern educational science. (Van Oers, 1998, p. 473).

Our understanding of science learning in particular changed after the so called “cognitive revolution” in psychology in the 1960s. Education and in particular mathematics and science education, has gained new insights from psychology, brain research and the social sciences. In the following section I will refer to a few movements which are influential not only in my work but in science education in general; these are 'constructivist learning', socio-cultural perspective of learning`, 'situated learning', 'expansive learning' and the 'knowledge creation approach to learning'. In addition I consider theories of 'organisational learning` fruitful to understand transformation of knowledge practices in this context.

2.2.1 Constructivist Learning

'Constructivist Learning' although as a concept rather meaningless because it is used in many variations and interpretations basically puts the focus on the individual that "constructs" knowledge him or herself while building upon already existing knowledge and ideas. In the constructivist context knowledge is a well-defined entity that can be considered independently of individual humans. A corpus of content knowledge has been acquired and passed on from generation to generation. Thus knowledge does not belong to any particular individual. It is more or less independent of the context in which it is used (e.g. scientific knowledge). Transfer of knowledge is expected to occur.

However it is the purpose of constructivist education to support the individual becoming creative and innovative through analysis, conceptualizations, and to synthesis prior knowledge and experience to create new knowledge. 'Social Constructivism' recognises that the learner's version of the truth is influenced by his or her background, culture or embedded worldview (see below).

2.2.2 The Socio-Cultural Perspective of Learning

A sociocultural approach to learning and development has the potential to recognize the essential relationship between learning processes and their cultural, historical and institutional setting. When we look at implementing 'Inquiry Based Science Learning' in botanic gardens, natural history museums or schools later, it will become evident that there are differences when this takes place in different countries e.g. Spain or in Austria, as well as differences brought about by the different role a teacher or an educator plays in these settings etc. Processes instead of forms of mental functioning are of concern to a socio-cultural background.

Wertsch (1991) cites Shweder 1990 when he argues:

> 'Cultural traditions and social practices regulate, express, transform, and permute the human psyche, resulting less in psychic unity for humankind than in ethnic divergences in mind, self and emotion' (p. 7),

Russian philosophers such as Vygotsky's, Leont'ev, Luria and others ideas are fundamental to the current understanding of sociocultural situatedness although Vygotsky's did not deal explicitly which the major topics currently applied in sociocultural studies. However, basic themes that run through Vygotsky's writing are fundamental to the sociocultural approaches to thinking and learning. Their power derives from ways in which they are intertwined. These are:

- attempts to understand the nature of mental processes by analysing static procedures of development only, will often be misleading.
- higher mental functioning in the individual derives from social life
- human action on both the social and individual planes is mediated by tools and signs (Wertsch,1999).

A fundamental assumption of sociocultural approaches to learning is that actions, rather than the human being or the environment considered in isolation, provide the entry point into the analysis.

> "When action is given analytic priority, human beings are viewed as coming into contact with, and creating their surrounding as well as themselves through the action in which they engage" (ibid, p. 8)

Habermas argues that many types of categories of action can be distinguished which are based on the relationship between the actor or learner and the environment. He takes Popper´s three world theory to categorize three type of environment in which activity takes place

- facilitated by physical objects or physical states
- facilitated by states of consciousness, mental states, behavioural disposition of act
- facilitated by "objective contents of thought" (e.g. scientific or poetic thoughts, works of art) (Wertsch, 1989)

Although language is often assumed as being the most important mediating action applied, these two other environments should not be neglected. Actions taking place between the actor and the world of physical objects may be summarised as producing or working with any kind of physical representations of understanding (Wertsch, 1989) such as hand-on tools, lesson plans, portfolios, posters etc.

Wertsch (ibid) particularly stresses the point that:

> 'the most central claim I wish to pursue is that human action employs "mediational means" such as tools and language and that this means shape the action in essential ways. According to this view it is possible as well as useful to make analytic distinction between action and meditational means but the relationship between action and medi-

> tational means is so fundamental that it is more appropriate when referring to the agent involved to speak of "individual(s)-acting-with-meditational-means" than to speak simply of "individual(s)". Thus, the answer to the question of who is carrying out the action will invariably identify the individuals in the concrete situation and the mediational means employed (p. 12)

This is in contrast with approaches that treat the individual as a passive recipient of information from the environment or approaches that focus on the individual and treat the environment as secondary, serving merely as a device to trigger certain developmental processes. The actor is assumed to reach a desired state by choosing means that have promise of being successful in the given situation and applying them in a suitable manner. This is based on a decision among alternative courses of action, with a view to the realisation of an end, guided by maxims and based on an interpretation of the situation (Wertsch, 1989).

A sociocultural approach to mediated action need not involve explicit comparison; the main criterion is that the analysis is linked in some way with specific cultural, historical or institutional factors. However the notion of "situatedness" implies a contrast with other possibilities. It is an accepted opinion that universality exists. Universalistic and sociocultural approaches are not assumed to be out-and-out contradictions, however educational research tends to often overemphasise universalistic approaches.

> 'Choosing to focus on either universal or sociocultural situatedness, one makes certain essential assumptions about which phenomena are interesting and deserve attention. The existence of these assumptions and their implications are not often appreciated however and the result has been endless misunderstanding and bogus argument. . . . It is a choice between two different research agendas, both of which need to be addresses and both, where possible, integrated (Wertsch, 1989, p. 7)'

Sociocultural approaches are well supported by a couple of philosophers and cultural psychologists; Locke, Decartes, Vigotsky, Leont'ev, Bakhitin, Piaget or Berry, Cole, Shweder or Toulmin are often cited in this context (Wertsch, 1989).

2.2.3 Situated Learning

The situated learning` movement is assumed to be . . .

> 'a radical critique of cognitivist theories of learning [because this theory is] emphasising the rational aspect of learning within communities of practice in contrast to the individualist assumption of conventional theories`(Handley et al., 2006, p. 641).

'Situated Learning' emphasises the idea that much of what is learned is specific to the situation in which it is learned. Hence learning is not something that takes place in the isolated individual only while acquiring new ideas, concepts and knowledge but is produced and reproduced in the social interaction of individuals when participating in a society. This participation is intrinsically tied to the context in which it takes place and implies both the aspect of knowing, as well as 'being and becoming' a member of a certain community. Most of all, participation in practice is assumed to be a necessary condition for learning. Modes of participation and becoming or being a member of the community are important (Anderson et al., 1996, Yakhelf, 2010).

In 1991, Jean Lave and Etienne Wenger published their book, 'Situated Learning: Legitimate Peripheral Participation' and introduced an epistemological principle of learning which was termed 'Community of Practice (CoP) and Situated Learning'.

The authors explained their theory of learning through an apprenticeship model by which newcomers to a community learn from other participants, during which time they are allowed to take over more and more tasks in the community and gradually progress to become 'masters' and enjoy full participation. This earlier perspective implied that

> 'legitimate peripheral participation in a community inevitably leads to full socialisation, thus resembling earlier socialisation theories following Vygotsky'. (Handley et al., 2006, p. 643)

Members of a CoP are expected to develop a mode of belonging and an identity in practice.

However, later both authors admitted that various forms of participation are both possible and fruitful and that becoming a full participant might not be aspired by all members of such a community.

The concept of Communities of Practice has been similarly taken across social, educational and management science and is currently one of the most articulated and developed concepts within broad social theories of learning (Barton & Tusting, 2005).

However as it happens frequently in education:

> 'the concept of communities of practice has been taken up and used by people working in many different areas. It has had an immediate appeal and perceived usefulness across a range of situations. Like any useful concept people have used it in a variety of ways, some have kept close to the original formulations and some developed it. Some have found it to be exactly what they want and others have criticised it and identified its limitations, proposing alternatives. Some have taken the whole theoretical apparatus of situated learning. Other have taken just the phrase and adapted it to their own uses combining it with concepts from other fields

> and incorporating it into other theories. For some it has become a central concept which a whole theory revolves around; for other it has been more peripheral and has been incorporated into other theories. This is probably the fate of any useful concept'. (Barton & Tusting, 2005, p. 2)

Etienne Wenger, cited by Booth and colleagues (2004) put it like this:

> 'It takes time for CoPs to emerge, flourish and to become productive. More important, they cannot be mandated or managed in a heavy-handed way. CoPs, then, are an investment in the organization's future, not a quick fix to be applied for the sake of short-term gain. Most important, many will exist whether or not management chooses to encourage and support them; they are a natural part of organizational life. And that means they require a minimal investment on the part of the organization.'

Therefore these communities are characterised and define themselves along the following dimension (Booth et al., 2004, Amin & Roberts, 2006).

- *Members show a mutual engagement:* they interact with each other in many ways. This engagement binds members together in a social entity.
- *Members are joined by an enterprise*: they have a common endeavour which is understood and continuously renegotiated by its members
- *The community shares a repertoire of common resources* such as language, style, routines, sensibilities, artefacts; resources that members have developed over time and by means of which they express their identities as members of the group
- *The community negotiates meaning in practice*

However, it is important to emphasise that CoP cannot be prescribed or installed to facilitate learning processes. They need to develop naturally and can be guided or supported by people interested in their development. For Wenger (1998) CoPs are important places of negotiation, learning, meaning, and identity.

Wenger (2002) does not restrict the concept of CoP to the school context only but believed that in a CoP, social learning occurs as soon as people who have a common interest in some subject or problem collaborate over an extended period of time to share ideas, find solutions and build innovation.

Based on this notion he argues that CoPs move through various stages over time which can be characterised by different levels of interaction among the members.

Wenger (1998) argues that the existence of a CoP may not be evident to its members because

> 'a community of practice' need not be reified as such in the discourse of its participants' (p. 125).

Nevertheless, he argues, a community of practice does display a number of characteristics including those listed below (Amin & Roberts, 2006)

Key characteristics of a Community of Practice compiled from Wenger (1998, p. 125/6).

- Sustained mutual relationships — harmonious or conflicting
- Shared ways of engaging in activities
- The rapid flow of information and propagation of innovation
- Absence of introductory preambles, as if conversations and interactions were merely the continuation of an on-going process
- Very quick setup of any problem to be discussed
- Substantial overlap in participants' descriptions of who belongs to the CoP
- Knowing what others know, what they can do, and how they can contribute to an enterprise
- Mutually defining identities
- The ability to assess the appropriateness of actions and products
- Specific tools, representations, and other artefacts
- Local lore, shared stories, inside jokes, knowing laughter
- Jargon and shortcuts to communication as well as the ease of producing new ones
- Certain styles recognised as displaying membership of the CoP
- A shared discourse reflecting a certain perspective on the world

Amin and Roberts (2006) argue that:

> 'Since the study by Lave and Wenger (1991) there has been an explosion of research on CoPs, and broader practice-based approaches, to learning and knowledge generation in a variety of diverse settings. Much of this literature, whether it reveals the existence of CoPs or reports on the application of the framework to particular learning and knowledge generation contexts, works with definitions that are far from the original conceptualisation of CoPs [. . .]
>
> Alongside the increasing popularity of communities of practice research, the approach has begun to attract criticism concerning, for instance, the neglect of power, its failure to take into account pre-existing conditions such as habitus and social codes, as well as its widespread application within organisational studies beyond its original focus on situated learning, and the term 'community' itself, which is problematic, embodies positive connotations and is open to multiple interpretations' (p. 4)

For Yakhelf (2010) learning a practice is not only to become a member of a community but also to be able to reflect upon what is lived, experienced and imagined.

> 'The link between knowing in practice (being a practitioner) and knowing a practice (or the result of the process of being a competent practitioner) is reflexivity. Knowing in practice requires participating competently in the knowledge embedded in that practice. For knowing a practice entails disembodying knowledge through an act reflexive knowledge' (p. 41).

Although originally used to describe a mode of social learning, it is now clear that CoPs are seen as having an impact far beyond their original field. They explain learning taking place in a wide range of educational areas as well as in business management or even politics.

According to Barton and Tusting (2005) the CoP based 'Theory of Situated Learning':

- appears to resolve some pervasive concerns of social sciences about learning
- represents a theory of learning which acknowledges networks and groups which are informal and not the same as formal structures
- allows for groups which are distributed in some ways and not necessarily in face to face contact
- the overall apparatus is a significant rethink of learning theory of value to anyone wanting to take learning beyond the individual
- is attractive as a middle-level theory between structure and agency which is applicable to and close to actual life and which resonates with detailed ethnographic account of how learning happens.
- Has been proved as a theory and has value in practice.

Part of its appeal may be nurtured by the idea that CoPs are seemingly natural formations which enhance learning. This is important for those aiming to implement change.

The Concept of CoP takes learning out of the formal classroom and addresses the variety of groups and locations where learning takes place such as teacher professional development offers or learning through educational projects and collaboration, in the workplace or even in everyday life.

2.2.4 Organisational Learning

As mentioned earlier many scholars have dealt with finding ways to deal with the area of conflict between the learning as an individual task or as a team work. One approach is the so called 'integrationist perspective' by developing a theory of 'organisational learning' (Starkey et al., 2004).

According to this perspective Dyck and colleagues (2005) argue that 'organisational learning begins with cognitive processes of individuals and is enhanced and preserved by organisational processes (p. 388)

If learning is valued as a situated process in a social context the individual learner cannot be the only centre of attention. The social group, subgroup or organisation in which this learning takes place has to be recognises as an entity for learning. It is necessary to understand the process through which individual learning advances organisational learning and to address the role individual knowledge and memory plays in the process through which individual learning becomes embedded in the organisations memory and in its structures.

'Organisational memory and knowledge' is the capability all members of an organisation have developed collectively over time. Its application depends on historically evolved collective understanding and experience. To draw distinctions in the process of carrying out their work in a particular concrete context, members of the organisation enact sets of generalisations (Kim, 2004).

How learning is expected to take place, what is valued as important and what is assumed to be 'good teaching' at Botanic Gardens, Zoos or Natural History Museums is not only a matter of each individual educator education and understanding. It is influenced by organisational traditions, knowledge and experience accumulated over time. This may or may not be recognized or valued explicitly.

Organisational knowledge can be embedded in a variety of repositories such as educational programmes, including individuals, routines, and trans-active memory systems. A collective understanding of organisational knowledge is seen as a key to understanding organisations' growth. This knowledge enables the organisation to use its resources accordingly. It is a distinctive way of thinking and acting in the world (Kim, 2004).

Thus from this perspective organisational learning is defined as a change in the organisation's knowledge that occurs as a function of experience. Organisational knowledge herein includes declarative knowledge, such as facts, and procedural knowledge, such as skills and routines which are shared in a particular community. Organisational knowledge may be measured either by the cognition of organisational members or by taking a behavioural approach. The latter focuses on knowledge embedded in performance such as accuracy or speed etc. or in practices or routines. Changes to those are accepted as changes in knowledge. Thus organizational learning can be defined as a change in the range of potential behaviours. However, it needs to be acknowledged that organisations may acquire knowledge without a change in behaviour (Argote, 2013).

When assessing knowledge by measuring changes in practice or performance, tacit as well as explicit knowledge is captured. This may circumvent the limitation of current approaches to measure learning by assessing changes in cognitions through questionnaires and interviews (Hodgkinson & Sparrow, 2002).

In this work I focus on knowledge embedded in practice and view changes as indicative that organizational learning occurred (Argote, 2013).

At a practical level, the ability to learn and adapt is critical to the performance and long term success of organizations. Because organizational learning occurs over time, studying organizational learning requires time and series of longitudinal data. However, we need to be aware, that behavioural approaches to analysing learning need to be sensitive to other factors that might affect change in behaviour (Argote, 2013).

> 'If we view a group as a mini-organisation whose members contribute to the groups shared mental models, then the model can represent group learning as well as organisational learning. A group can then be viewed as a collective individual, with its own set of models, which contributes to the organisation's shared mental model and learning. This is consistent with the notion that groups themselves are influenced by organisational structure and type of management style and therefore can be treated as if they were "extended individuals" (Kim, 2004, p. 41).

Organisational/sub-group learning occurs in a context which includes the organisation and the external environment in which the organisation or sub-group is embedded. Therefore as mentioned above a socio cultural approach to learning needs to be taken into account because this assumes that action is mediated and that it cannot be separated from the milieu in which it is carried out (Weber, 2008).

2.2.5 Expansive Learning

Activity Theory

Activity theory is a

> 'Philosophy and cross-disciplinary framework for studying different forms of human activity [. . . hence it is] a philosophical framework for studying different forms of human praxis as developmental process. Both individual and social levels are interlinked at the same time' (Kunit, as cited in Jonassen, 2000)
>
> 'Activity theorists argue that conscious learning and activity (performance) are completely interactive and interdependent. Activity cannot occur without conscious (the mind as a whole) and consciousness cannot occur outside of the context of activity' (Jonassen, 2000, pp. 97–98)

Initiated by Vygotsky and his Russian colleagues the principles of "Activity Theory" evolved from Vigotsky's (1978) triangular model visualising the relationship between the stimulus (S) and the response (R) which is transcended by a complex mediating act (X).

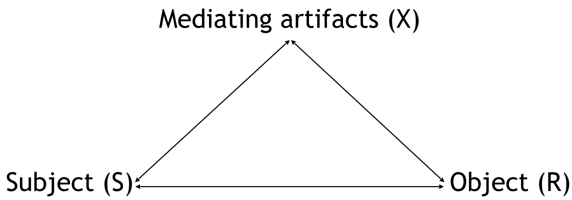

Figure 1: Common reformulation of Vygotsky's mediated act (Engeström, 2001).

Thus Vygotsky was first to insert "mediating acts" which are called "cultural artefacts" into human action.

> 'The individual could no longer be understood without his or her cultural means; and the society could no longer be understood without the agency of individuals who use and produce artefacts . . . . Objects became cultural entities and the object-orientedness of action became the key to understanding human psyche (Engeström 2001, p. 143)

The "cultural –historical approach" to Activity Theory, termed 'Second Generation Activity Theory' by Engestöm (2001) included Leontev' s idea that the "difference between the individual action and a collective activity" needs to be considered with Il'enkov adding "internal contractions as the driving force of change and development". Western researchers included other influential domains, such as rules, the community and the division of labour, which provided "Activity Theory" with the potential of a great diversity of applications (Engeström, 2001).

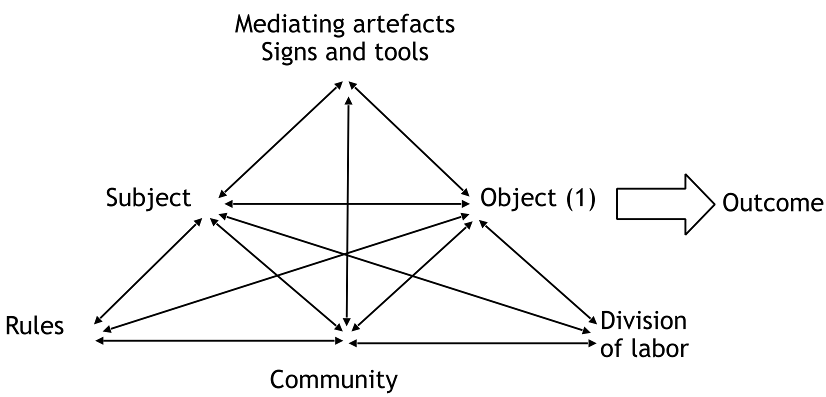

Figure 2: The structure of a human activity system (Engeström, 1987, p. 78).

Michael Cole (1988) pointed out that this second generation activity theory was insensitive towards cultural diversity and should be seriously challenged.

However the 'Third Generation of Activity Theory' needed to develop conceptual tools to understand dialogue, multiple perspectives and networks of interacting activity systems.

According to Engeström (2001), aspects such as "dialogically", the notion of Activity Networks, Actor Network Theory, the concept of Boundary Crossing and the concept of Third Space have shaped further discussion. These developments opened the doors for the formation of the 'Third Generation of Cultural Historical Theory; which was published in 2001 and which is most appropriate in my context.

> 'the object (e.g. lesson plan) moves from an initial state of un-reflected situationally given "raw material" to a collective meaningful object constructed by the activity system (partner institution) and finally to a potentially shared or jointly constructed object (e.g. best lesson plan published by partners at the end of the INQUIRE project duration). Thus the object is a moving target, not reducible to short-term goals (p. 136)

In relation to the case study presented in the second part of this work the current shape of Activity Theory may therefore be summarises by 5 principles (Engeström, 2001):

1. The prime unit of analysis is a collective, artefact-mediated and object-oriented activity system (INQUIRE partner organisation) seen in its network relations to other activity systems (INQUIRE consortium). Goal directed individual and group actions (course design, lesson plans, portfolio of evidence, posters presented at meetings etc.) are relatively independent but subordinated units of analysis, understandable only when interpreted against the background of the entire activity system (INQUIRE project).
2. An activity system is always a community of multiple points of view, traditions and interest. The division of labour creates different positions for

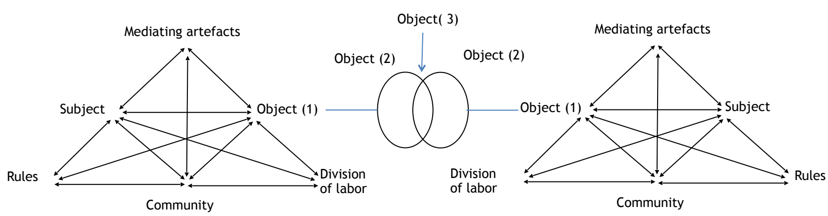

Figure 3: Two interacting activity systems as minimal model for the third generation of activity theory (Engeström, 2001 p. 136, cited by Kapelari, 2015).

the participants (INQUIRE-Management Board, hierarchy in partner institutions). The participants bring with them their own diverse histories and the activity system itself carries multiple layers and strands of history encapsulated in its artefacts, rules and conversations. The network multiplies this 'muti-voicedness' and is a source of both problems and innovation, demanding actions of translation and negotiation.

3. Activity systems get transformed and shaped over the length of time: The History of the entire activity system (INQUIRE project) needs to be studied both as a 'local history of the activity and its objects' and as a 'history of the theoretical ideas and tools that shape the activity'.
4. Activity systems are open systems. Contradictions accumulate structural tensions within and between activity systems. When one activity system adopts new elements from outside this may clash with already existing ones, generating disturbance and conflict, but also innovative attempts to change the particular activity.
5. There is a possibility of expansive transformation in activity systems; however they move through relatively long cycles of qualitative transformation. As the contradictions of an activity system are aggravated, some individual participants begin to question and deviate from established norms. An expansive transformation is accomplished when the object and motive of the activity are reconceptualised to embrace radically wider horizon.

Expansive Learning and Knowledge Creation

'Expansive Learning Theory' adds another set of 'somewhat philosophical' perspectives which need to be considered in the context of this work.

> 'Expansive learning refers to processes in which an activity system, for example a work organization, resolves its pressing internal contradictions by constructing and implementing a qualitatively new way of functioning for itself'. (Engeström, 2007, p. 24)

Engeström argues that 'Expansive Learning' is – in reference to Lave and Wenger's original legitimate-peripheral-participation framework – not a one way movement from incompetence to competence but includes horizontal movement while learners construct new concepts or objects for their activity. Thus expansive learning

- is concerned with learning of new forms of activities as they are created rather than the mastery of already known and well-defined existing knowledge and skills.

- is mainly concerned with collective learning rather than individual learning and
- although it acknowledges vertical learning Engeström (2000) suggests that 'we focus on constructing a complementary perspective, namely that of horizontal or sideway learning and development (p. 533)'

Contradictions originating within an activity system or between two or more activity systems are supposed to trigger change. It is assumed that human collective activity systems move through a cycle of change, which includes 7 steps:

1. Questioning/primary contradiction
2. Historical analysis and/or actual empirical analysis
3. Modelling the new solution
4. Examining the new model
5. Implementing the new model
6. Reflection on the process and realignment with neighbours
7. Consolidating the new practice

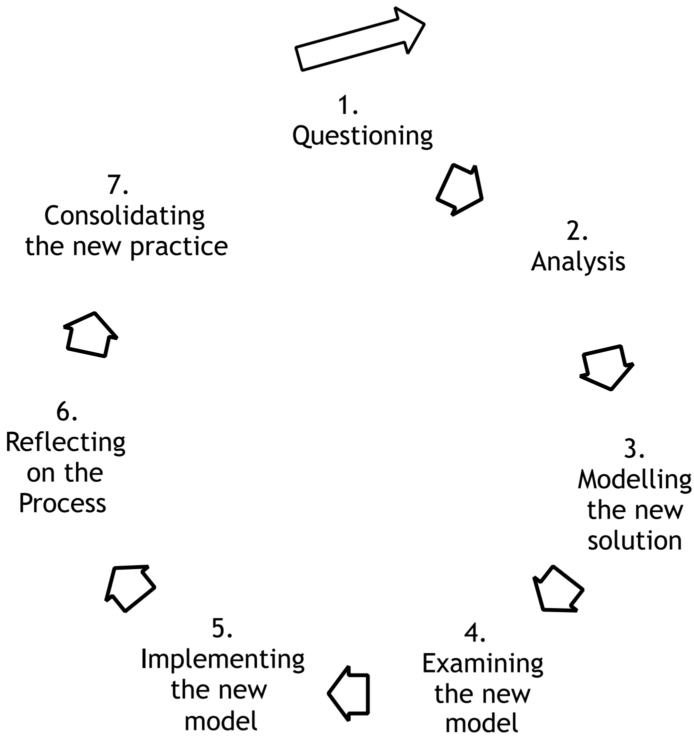

Figure 4: The expansive learning cycle (Engeström, 2007, cited by Kapelari, 2015).

'Ascending from the abstract to the concrete' is achieved through specific epistemic or learning actions. Together these actions form an expansive cycle or spiral. The process of expansive learning should be understood as construction and resolution of successively evolving contradictions in the activity system (Engeström & Sannino, 2010, p. 5).

Models of learning as a cyclic process are manifold in research literature and often show, beside differences, many similarities. E g. John Dewey´s 'Instructional Model of Learning' includes defining the problem, noting conditions associated with the problem, formulating a hypothesis for solving the problem, elaborating the value of various solutions, and finally testing the ideas to see which provide the best solution for the problem.

Bybee and colleagues (2006, p. 5) cite Dewey`s article 'Democracy and Education' published about a 100 years ago, as such

> 'Dewey further describes the relationship between experience and thinking. He summarizes the general features of the reflective experience: (i) perplexity, confusion, doubt, due to the fact that one is implicated in an incomplete situation whose full character is not yet determined; (ii) a conjectural anticipation—a tentative interpretation of the given elements, attributing to them a tendency to affect certain consequences; (iii) a careful survey (examination, inspection, exploration, analysis) of all attainable consideration which will define and clarify the problem in hand; (iv) a consequent elaboration of the tentative hypothesis to make it more precise and more consistent; (v) taking one stand upon the project hypothesis as a plan of action which is applied to the existing state of affairs: doing something overtly to bring about the anticipated result, thereby testing the hypothesis' (p. 150).

Engeströms 'Model of Expansive Learning' however enables us to theorise group, community and work based learning and adds new perspectives. It describes the capacity of learners working collaboratively to interpret and expand the definition of the object of an activity and to respond to it in a way that is most appropriate to the situation/cultural context in which the object is applied. It emphasises knowledge that is embedded in practice and values both conceptual artefacts (ideas, opinions etc.) and material practices (e.g. lesson plans).

Expansive learning not only values 'the process of vertical improvement along some uniform scales of competences' but recognises a horizontal movement, the exchange and hybridisation between different cultural contexts and standards of competences` (Engeström & Sannino, 2010, p. 2).

In their article 'Models of Innovative Knowledge Communities and three Metaphors of learning' Paavola and colleagues (2004) discuss Nonaka and Takeuchi´s 'Model of Knowledge Creation', Engeström's 'Model of Expansive

Learning` (s.p. 35) and Bereiter's 'Model of Knowledge building' (mentioned above) and argue

> 'The models we have reviewed emphasize that previous conceptions of learning have been inadequate for dealing with innovative, expansive or progressive aspects of knowledge advancement in a profound way. Neither acquisition nor the participation approach has been sufficient, at least not in ideal typical forms (p. 569)

They argue that

> 'The main focus of the acquisition perspective has been on the acquisition of knowledge that is more or less ready-made or on clear-cut developmental rules or phases, rather than on the creation of something "expansively" new. The participation perspective typically has focused on examining how knowledge and practices are passed from one generation to another in traditional cultures or in cultures without substantial and deliberate changes or cultural transformations (see, e.g., Lave and Wenger, 1991). The focus has been on how newcomers become old-timers by participating in cultural practices, not on the radical advancement of knowledge or practices '(p. 569).

Although these arguments indicate a rather limited view on 'knowledge acquisition' and 'knowledge participation' and authors attenuate these claims while continuing, these arguments reveal a commonly recognised weak point in education practice in general and in science education practice in particular, which still mainly focuses on accumulating facts, predetermined outcomes and following a traditional path.

In the context of my work the metaphor of 'knowledge creation' is rooted in Engeströms model of expansive learning is most appropriate because:

> 'knowledge-creation models conceptualize learning and knowledge advancement as collaborative processes for developing shared objects of activity. Learning is not conceptualized through processes occurring in individuals' minds, or through processes of participation in social practices. Learning is understood as a collaborative effort directed toward developing some mediated artifacts, broadly defined as including knowledge, ideas, practices, and material or conceptual artifacts. The interaction among different forms of knowledge or between knowledge and other activities is emphasized as a requirement for this kind of innovativeness in learning and knowledge creation [. . .]. A broader perspective is needed because it is important to understand those [cultural] practices through which innovative knowledge communities function. The focus is not on the certainty of knowledge but how knowledge is used and how it is developed. The models

of innovative knowledge communities are important just because they analyze processes of knowledge creation in a detailed and concrete way. Such analysis requires that both social and epistemological perspectives be taken into account.' (Paavola et al., 2004, pp. 569–570).

2.3 Science Education in the 21st Century

In the 20th century, the main goal for science education in Austria was to deliver a certain amount of content knowledge, which was often considered to be solid reproducible facts. Those able to accumulate and reproduce this knowledge were considered to be well prepared for a scientific carrier.

21rst century science education is no longer valued only by those wishing to go into scientific or scientific related careers but by all members of an educated society. Supporting every child to become "*scientifically literate*" is now more than a buzzword amongst science educators and curriculum planners and science education authorities in Europe although it may not be on the agenda of all science teachers yet and can manifest itself in in different ways.

The term "scientific literacy" is used to show that science knowledge is regarded an object of economic, political and cultural value, as important as 'basic skills' such as reading, writing or mathematics. Scientific literacy is considered to be important to have and useful for anybody who wishes to lead a successful life and become a major and active citizen of a modern society, able to question scientific outcomes, to value them for personal decisions and to act according to these decisions.

Since the PISA assessment gained influential coverage in both the media and political discussions, the concept of '*Scientific literacy for all students*' is becoming more and more popular in Austria as well as other countries.

2.3.1 The Concept of Scientific Literacy

Given the length of history for the rhetoric of science education one would presume that there would be a clear definition of *scientific literacy* already. As with the terms 'Nature of Science' or 'Inquiry Bases Science Education', this is unfortunately not the case.

The term "Scientific Literacy" first appeared in the educational literature of the US in papers authored by Paul Hurd and Richard McCudy in 1958 and since that time the various definitions have been discussed in great detail, with emphasis placed on one or another aspect that are shared across many definitions (Hodson, 2007).

The European science education community, that joined the discussion a couple of years later, frequently cites the OECD PISA Framework when it refers to scientific literacy as a global goal for science education.

In 1999 the OECD pointed out that:

> 'An important life skill for young people is the capacity to draw appropriate and guarded conclusions from evidence and information given to them, to criticise claims made by others on the basis of the evidence put forward, and to distinguish opinion from evidence-based statements.' (OECD, 1999, p. 59)

In 2006 PISA OECD defines *Scientific Literacy* as the capacity to

- use scientific knowledge,
- identify questions and
- draw evidence based conclusions in order to understand and help making decisions about the natural world and the changes made to it through human activities.

It is important to emphasise that both scientific knowledge (in the sense of knowledge about science) and the process by which this knowledge is developed are essential for scientific literacy. They are bound together in this understanding of the term (OECD, 2007).

Besides a well-developed understanding of fundamental scientific concepts, the limitation of scientific knowledge and the nature of science as human activity, the PISA definition also implicitly includes students' abilities to read, write and understand scientific language as well as being able to analyse, extract meaning, interpret and evaluate scientific texts.

> 'It is the scientific language that shapes our ideas, provides the means for constructing scientific understanding and explanations, enables us to communicate the purposes, procedures, findings and explanations of our inquiry and allows us to relate our work to existing knowledge and understanding' (Hodson, 2007, p. 2).

'Drawing evidence based conclusions' stands for a whole set of abilities that scientifically literate people are expected to have such as:

- being able to identify questions which can be answered by science.
- knowing how and whether this scientific knowledge can be applied
- being able to select and evaluate information and data, cautiously and consciously (PISA 2006)

The PISA scientific literacy definition does not mention 'intellectual independence and autonomy' explicitly although it is very likely that these aspects are covered (Hodson, 2007).

Intellectual independence for non-scientists has been a goal of science education for decades (Norris, 1997) and is one INQUIRE learning goal I will address in the second part of this work.

- 'To be intellectually independent is to assess on one one´s own the soundness of the justification proposed for a knowledge claim'. Depending on the source, either based on personal science content knowledge or on the basis of good reasons or evidence for believing that somebody else has good reasons for his or her believes, the justification requires more or less understanding of the scientific content (Aikenhead, 1990, p. 132 cited in Norris, 1997)
- [. . .] 'understand and help make decisions' includes valuing the understanding of scientific knowledge as a goal which needs to be achieved and which can be applied in the context of human values related to social, political and economic dimensions. 'Science is in many respects the systematic application of some highly regarded human values – integrity, diligence, fairness, curiosity, openness to new ideas, scepticism, and imagination. Studying science will instil these values. (AAAS 1989, cited in Hodson 2007, p. 11)
- [. . .] 'the natural world and the changes made to it through human activities' refers to physical settings, living things and the relationship among them. Decisions about the natural world include those associated with issues which address oneself and/or the family, the community and the world as such (PISA 2006).

Science education plays an important role in providing the context and supporting students to develop these abilities. Science is concerned with developing structured and reproducible approaches for testing ideas and offers theories based on evidence. While including creativity and imagination the critical and rational perspective is not neglected and the combination of both is the approach science takes to advance our understanding of the natural world (OECD, 1999).

The OEDC framework for testing students' knowledge and skills PISA defines Scientific Literacy as an individual's:

- Scientific knowledge and use of that knowledge to identify questions, acquire new knowledge, explain scientific phenomena and draw evidence-based conclusions about science-related issues
- Understanding of the characteristic features of science as a form of human knowledge and enquiry
- Awareness of how science and technology shape our material, intellectual and cultural environments
- Willingness to engage in science-related issues, and with the ideas of science, as a reflective citizen (OECD, 2013, p. 100).

Thus Scientific Literacy has a significant metacognitive dimension. Students need to know what they know, and when the knowledge can and should be utilized as well as how to recognize deficiencies in their own knowledge and how to compensate for them (Hodson, 2007).

Science Literacy is therefore more rooted in learning about science and doing science than in learning science facts only.

Why is it important to become scientifically literate?

PISA 2006 points out that Scientific Literacy does not presume a dichotomy where people are either scientifically literate or scientifically illiterate. It is a continuum, which progresses from less developed to more developed.

A cultural approach to Scientific Literacy includes a societal and an individual dimension. The individual is asked to engage in a life-long learning process. It is assumed that good science teaching has the potential to provoke this perpetual process. Thus in our knowledge society the scientifically literate individual is expected to gain a range of profits.

A public understanding of science is assumed to be important for a society as a whole, because Scientific Literacy . . ..

- increases the competitiveness and economic strength of a society (s. p. 50ff)
- increases the number of recruits for science jobs (students at universities, researchers, people working in the industry and technology sector etc. (s. p. 50ff)
- provides greater financial support for science research, industry and technology
- leads to more realistic public expectations as to what science can do (awareness of the characteristics of science enquiry)
- helps counter opposition from religious groups
- counteracts anti-science behaviour
- supports the acceptance of science/scientists
- reduces public suspicion about science based innovations (e.g. GMO)
- supports scientists as expert witnesses for both sides in legal disputes
- values what science does for the economy (e.g. jobs, money to earn). Scientific literacy is therefore regarded as a form of human capital that sustains and develops the economic well-being of a nation
- enriches the cultural health and the intellectual life of a nation
- enhances democracy and responsible citizenship

Any individual member of society who works towards becoming scientifically literate may result in the ability to;

- make informed decisions affecting one's health, life style, security, economic well being

- live up to the demand of advanced science skills; people are expected to develop their learning skills and learn to progress within their jobs
- value science as helpful for learning, reasoning, thinking creatively, making decisions, solving problems
- value the intellectual, aesthetic, moral and ethical benefits of science
- develop one's own ethical standards and codes for responsible behaviour
- take responsibility for decisions about one's own health and the environment

It is assumed that Scientific Literacy supports people to become and stay responsible and active citizen in the community.

Hodson (2007) argues that a curriculum aiming for supporting students to become scientifically literate should give insight into what science is and what scientists do. This includes various elements such as:

- exploring the nature of science
- exploring various views of science
- engaging in scientific inquiry
- making the case for the history of science

However, the concept of scientific literacy has been reconceptualised by educators and policy makers to a large extent. This diffusion of the concept can be interpreted as a result of economic, political and cultural logic which have been applied. Each of these logics has an influence on the particular mix of what is considered more or less important whenever learning goals are defined and implemented in curricula, instructional material and in assessment. Eneaney (2003) argues that:

> 'the public discourse about scientific literacy is driven by economic and political logics while curricular implementation is grounded in world culture (p. 218)

Dillon (2009) argues:

> The longevity of the term scientific literacy relies on its ability to be seen as an umbrella for radical different philosophies of science education. However, the evidence suggests that when attempts are made to effect curriculum change to promote 'scientific literacy' the unreconciled philosophical clashes hinders progress (Dillon, 2009).

However, discussions revolving around the concept of scientific literacy raise the question whether the tension between 'those three logics' or the 'unreconciled philosophical clashes' should be blamed only or whether we need to reconsider the key question: 'what does it mean to be educated in this days and age?' We may need to question our assumption about 'global education as the ultimate goal for all children'. Global knowledge, global skills and global values such as those considered important in the 'scientific literacy' debate;

> '[. . .] cannot resolve the crisis of meaning in our societies because they are not asking the important questions about what we stand for and which knowledge we should teach children [. . .] Values of diversity, tolerance, empathy, participation, or being a 'global citizen' all avoid asking difficult questions about which ideas and cultural practices are better than others'. (Standish, 2012)

The latter questions are those practitioners need to answer on a daily basis. They need to decide what they want students to know at the end of the day. As we will see later the process of descending from an abstract understanding of a concept such as scientific literacy, inquiry, nature of science as they are discussed among scholars, to the concrete teaching and learning in an everyday science classroom consequently leads to individual or organisational interpretations and reconstructions of the concept. The question is whether it is possible or even desirable to train practitioners to adopt values and practices that have been developed by others without engaging in expanding a particular understanding that may resemble their own values, their socio cultural context, their attitudes, knowledge and skills.

Scientific Literacy and Environmental Education

The PISA in Focus 2012, Environmental Education report argues that today's students are growing up in a precarious natural environment. 'Climate Change' and the loss of biodiversity threaten ecosystems. The lack of clean water, the immense production of waste and polluted grounds jeopardise the health of millions of people every day.

Since individual actions have an impact on the environment it is assumed that scientific literacy' includes 'Environmental Literacy' because the actions of individuals have an impact on the environment.

Scientifically literate people are supposed to be equipped with knowledge about environmental issues and therefore tend to seek more information. Thus they are considered to be better prepared to make informed decisions about their daily life and how they lead it.

The EU PISA in focus report shows that, across the OECD 19% of 15-year olds perform at the highest level of proficiency in environmental science (Level A) PISA scale). At this level students can constantly identify, explain and apply scientific knowledge related to a variety of environmental topics. They can

> '[. . .] link different information sources and explanation and use evidence from those sources to justify decisions about environmental

> issues. They clearly and consistently demonstrate advanced thinking a reasoning in the science relevant to the environment and use the understanding to develop arguments in support of recommendations and decisions in both the social and the global situation (OECD, 2012, p. 2)

A large proportion of students are under-equipped to meet environmental challenges. Across the OECD countries the average of 16% of the students performs below the baseline level of proficiency.

However the interdisciplinary field of environmental education (EE) has been in existence for c. 40 years. It has received considerably more attention in recent years as contested issues about the environment, such as environmental pollution, environmental protection, climate change and sustainable living become common topics in public, media and political debates.

Attempts to characterise the concept of Environmental Education as well as that of Sustainability Education, however, have come up with a multiplicity of interpretations.

The United Nation Conference on Environmental Development (UNCED) referred to education as being critical to promoting sustainable development and for improving the capacity of people to address environmental and development issues;

> 'There is a need to increase people's sensitivity to, and involvement in, finding solutions for environment and development problems. Education can give people the environmental and ethical awareness, values and attitudes, skills and behaviour needed for sustainable development. To do this, education needs to explain not only the physical and biological environment, but the socio-economic environment and human development' (UNCED, 1992, para 36.3.).

Thus as an interdisciplinary field Environmental Education aims to:

- Foster clear awareness of, and concern about, economic, social, political, and ecological interdependences in urban and rural areas.
- Provide every person with the opportunity to acquire the knowledge, values, attitudes, commitment, and skills needed to protect and improve the environment.
- Create new patterns of behaviour towards the environment in individuals, groups and societies as a whole.

Regula Kyburz-Graber (2013) summaries a strand of environmental education research which developed as a reaction to social requests concerning environmental problems:

- promoting individual behavioural change through improving strategies and research

- enhancing environmental awareness through environmental literacy, usually closely linked to natural literacy
- enhancing humans relationship to nature and ecological awareness through experiencing nature
- promoting action competence through action oriented learning
- promoting ethical reflection and awareness of cultural context and diversity
- becoming a critical thinker through transformative and critical education

Bailin and colleagues (2010) argue, in respect to education for critical thinking, that:

> 'Becoming proficient at critical thinking itself involves among other things the acquisition of certain sorts of knowledge. For example the knowledge of certain critical concepts which enable one to make distinctions is central to critical thinking' (p. 272).

Environmental science is taught in schools in almost all OECD countries. Most students learn about it in subjects such as 'natural sciences', 'biology' and 'geography'.

It is generally agreed by researchers that learning about the environment outside the classroom has a great potential to support students learning (Rickinson et al., 2004). According to school heads questioned in the course of the 2006 PISA study most 15 year old students attend schools that provide at least one 'Out of the Classroom' (LOtC) learning activity offer. Outdoor education and trips to museums are the most common activities.77% of students in OECD countries attend schools that offer outdoor education and 75% offer schools visits to museums, 65% offer school visits to science centres.

School plays an important role in providing information about air pollution, energy, extinctions of plants, etc. Thus most often students learn about environmental matters in school. High performing students also refer to media and the internet to improve their knowledge (Grafendorfer & Neureiter, 2009).

Zint (2012, p. 9) summarises potentially successful practices and assumes that instructional practices cannot foster changes in behaviours if they:

- lack clearly defined behavioural outcomes and objectives,
- focus on general environmental knowledge or attitudes (vs. ones related to desired behaviours),
- are imposed from the top down (i.e. not designed to meet audiences' needs),
- passive (i.e. information transmission focused, lacking participant involvement), and
- are short (i.e. a few hours) in duration.

However they do foster changes in behaviours if they:

- have behavioural outcome and objectives,
- are designed based on behaviour theories/models [see (Heimlich & Ardoin, 2008) for a review of relevant theories/models],

- consider participants' needs, context and background,
- incorporate experiential learning (e.g. field trips, in service learning), and
- are longer (i.e. 1–2 years) in duration.

Based on science education research findings Zint (2011) suggests to apply the following instructional practices and cites authors accordingly (p. 10)

- (long term) place-based hands-on science inquiry (Bodzin, 2008; Endreny, 2010; Patterson & Harbor, 2005),
- outdoor learning experience (Bodzin, 2008),
- demonstrations/models that make invisible parts of watershed systems visible (Covitt et al., 2009),
- instructional technology (e.g. Web-based GIS maps and google Earth) Bodzin, 2008)

Scientific Literacy and Plant Science

Within the last few decades a phenomenon became more and more visible in civilized countries. As more people are living in urban or suburban environments, daily interactions with plants fewer than at any time in human history. This urbanization is therefore fostering a profound and continuing disconnection with nature where plants are becoming 'alien species' for young children and future generations (Richards & Lee, 2002). There is however an urgent need to raise student and other people´s interest in plants. Biodiversity loss, climate change, feeding our world's population, increasing limitation of drinking water resources and the need for comprehensive health care are only a few of the biggest challenges for our population in the 21st century. None of these problems will be solved without profound knowledge about plants, how they live and what can do for us. Learning about plants should therefore be a central pillar within science education that focuses on developing scientifically literate mature citizens.

Becoming scientifically literate in Austria

According to the national curriculum, the goal of science education in Austria is to develop scientific competences (BiFI, 2011). Grafendorfer & Neureiter (2009) published a study based on the Austrian specific data collected via the PISA 2006 assessment. They looked closely at how Austrian students experience science learning in class. Four categories of science teaching approaches were assessed:

Approach 1: Students engage in discussions, are asked for their opinions and ideas and to explain these

Approach 2: Students conduct experiments in the laboratory by following given instructions. They watch teachers demonstrating these experiments and they are asked to draw conclusions from them.
Approach 3: Students are exposed to inquiry based learning
Approach 4: Science knowledge is related to an everyday context.

Results showed that Austrian 15–16 year olds rarely experience inquiry based (IB) learning in class. Interestingly, only 5% of high level performing students (PISA Level 5 and above) state that they are often asked to do investigations and draw their own conclusions (the IB approach) whereas students that stated that they often experienced IB in class, often showed a low level proficiency (PISA, level 1 and below) - c37% of the Austrian students who stated this were registered at this low PISA level.

Discussion related and context related science teaching approaches are most commonly experienced by Austrian 15-to 16 year olds in science classes. While the Austrian emphasis on discussion related methods is higher, doing experiments, inquiry bases learning and context related learning is below OECD average.

Austrian head-teachers report on various activities that support student engagement in science. The most popular is taking part in fieldtrips and excursions; these are supported by 90% of all participating schools. 70% of all Austrians schools provide opportunities for students to learn about environmental issues via fieldtrips into nature as well as visits to museums and science centres.

Austrian 15–16 year olds mainly learn about scientific topics in school. 30% of the Austrians students declare that they gain additional knowledge about the topics ‘nuclear power’ and ‘climate change’ from the media. 50% also learn about ‘health and diet’ at home. 50% of this age group spent 2–6 hours/week on science classes in school. 17% do not have any science classes. Learning about science via free choice activities appears to not be very popular with Austrian teenagers; 15–16 year olds never or rarely read about scientific topics in books (93%) nor do they watch science programs on TV (87%). Only 4% attend science groups regularly or often.

Looking at the Austrian curriculum, science education has a social responsibility to support students in a world where knowledge and technology are rapidly changing. This should be done to support students to acquire the knowledge and competences, alongside discussion techniques in order to develop and become mature critical thinking citizens. The general educational goals, regarding the domain of nature and technology in the Austrian curriculum for 10–18 year olds (AHS, NMS, HS) are:

- to develop knowledge about interdependencies in nature which is considered essential to establish a conscious way of managing and using the environment by means of modern technology

- to develop an understanding for scientific phenomenon and ways of looking at questions and problems in mathematics, science and technology is regarded the foundation for inclusion in a modern technologically minded society.

Education in science should therefore convey basic knowledge, decision-making authority and the capacity to act. Students should be qualified to deal proficiently with the moral concepts and ethical questions connected with science and technology as well as with humans and their environment. Formalizations, modelling, abstractions and a concept of space should be conveyed as essential requirements for analysing and finding solutions to problems. (BMUKK, 2000).

Austrian curricula mirror the internationally discussed concept of scientific literacy, although the focus is primarily on what to convey more than on what to achieve. No particular focus is put on understanding the Nature of Science (NOS) in the way that the PISA concept of scientific literacy does.

The term '*scientific literacy*' is frequently translated in German as 'Naturwissenschafts-kompetenz' (Grafendorfer & Neureiter, 2009) or 'Naturwissenschaftliche Grundbildung' meaning 'basic scientific literacy' (Reinhold, 1997, Rost et al., 2005). The latter implies that people may reach different levels of scientific literacy. It is assumed that there are further stages of scientific literacy to reach after school, which might be achieved through a life-long learning process. However benchmarks for whether or not somebody has achieved this 'basic scientific literacy' are ill-defined. Although the PISA definition of scientific literacy described above is assumed to be broader than the processes included in most science curricula of participating OEDC nations, Austrian experts assume that the compliance with the Austrian Curriculum is comprehensive (Eder, 2009).

Economy based needs for improving science and technology education in Austria

A cultural approach values scientific literacy as being important for each individual human. Political, social and economic perspectives are often raised in addition to justify the need for improving science education in Europe.

Enhancing the knowledge level of a society is assumed to improve the competitiveness and the innovation potential of the whole nation.

Holzinger and Reidl (2012) published the study, 'The Humanresourcen Barometer' recently and show that human capital, which is the knowledge, skills and competences associated with each individual person, forms the basis of economic success not only for a company but the whole country. It also increases competitiveness as well as the potential for a nation's social development. An increasing in competitiveness has an effect on the job market, resulting in an increasing demand for higher qualified employees. Providing enough work-force for knowledge based economy challenges the education and employment market, particularly when one takes the demographics into account.

The Innovation Union Scoreboard (IUS, 2013) gives a comparative assessment of the innovation performance of the EU 27 member states and the relative strengths and weaknesses of their research and innovation systems. The overall ambition of the Innovation Union Scoreboard is '*to inform policy discussions at the national and EU level by tracking progress in innovation performance inside and outside the EU over time*'. The measurement focuses on the Summary Innovation Index (SII) which includes 'Enablers' (human resources, open, excellent attractive research systems, finance and support), 'firm activities' (firm investments, linkage and entrepreneurship, intellectual assets) and 'outputs' (innovators and economic effects).

Based on this index, EU states are put into four performance groups:

- Innovation Leaders, which is currently led by Sweden, followed by Germany, Denmark and Finland, who are well above the EU27 average.
- Innovation Followers, the group that Austria and the UK belong to, which are less than 20% but more than 10% above the EU average.
- Moderate Innovators, those less than 10% below but more than 50% below the EU27 average and
- Modest innovators are below 50% that of the EU 27. Bulgaria, Romania, Poland and Lithuania are at the bottom end.

Austria has recently been demonstrating a dynamic catching up process, putting the country into the 'Innovation Followers' group. Austria has to admit however that it has improved in some aspects but has not yet reached its goals to become an 'Innovation Leader'. The 'Humanressourcen Barometer' is looking at the Austria's development in great detail. Based on the findings of the Austrian Human Resources Development between 1999 and 2010 the following issues will need to be addressed in the future;

- The ageing of the human resource for in science and technology
- The demand by Austrian innovation strategies for a higher number of highly qualified human capital, which will be difficult to supply
- The lack of equal opportunities for women in science and technology which is currently leading to a decrease in the human capital in science and technology
- The tertiary education sector failing to supply the demand for highly qualified human resources in science and technology
- The fact that the demand for a higher human resource for science and technology is currently met through a high percentage of non-natives.

- The proportion of non-employed or inactive human resources in science and technology is very low in Austria leaving no scope to supply future demands with people who are already well educated.

Figures show clearly that Austria is improving in its efforts to raising the number of higher educated people in general. The years 2002–2011 show a 65% increase in students finishing their studies at university and 138% more graduating at colleges. These changes can be explained by the fact that an increasing number of colleges (Fachhochschulen) have been founded in Austria in the last 20 years and the by the implementation of 'bachelor' programmes.

Looking at these numbers in more detail, we recognise certain aspects that need to be considered for the delivery of science education and science education reform efforts in Austria.

Between 2002 and 2011 we see an increase of 40% of students signing up at universities in Austria. Science and Technology courses show about the same increase in student numbers (40% and 52% respectively). At colleges, technology and science is even more popular, with an increase of 81%-85% in student numbers.

This contradicts the European Commission's perception that the interest of young people in science and technology related careers is decreasing.

However, in relation to other academic subjects, the number of young people interested in science and technology studies is still low; in addition we still see a large discrepancy between the number of female and male students in science and technology related subjects. Most female students study pedagogy related studies the lowest numbers are seen in technology related studies. Male Students prefer to study the social sciences followed by technology and science related subjects (Holzinger & Reidl, 2012).

Taking the human resource development in our country into consideration, the Austrian science education systems obviously needs develop new strategies of how to counteract the current trend that young people, females in particular, tend to follow in their career choice.

2.3.2 Improving Science Education

Science Education has traditionally been assigned the role of transmitting knowledge. However, over the past 50 years, there have been dynamic changes in our conceptualisation of science learning and of science learning environments, integrating concepts such as 'situated learning' or the 'socio-cultural perspective of learning' (see. above).

These changes have important implications for how we interpret the role of inquiry in school science education programmes as well as curriculum development, teaching practices and assessment techniques (Duschl & Grandy, 2008).

Whereas traditionally science education mainly focused on the acquisition of a body of content knowledge and conceptual understanding, there is now an acknowledgement within science education that learners' should understand the nature of science knowledge and the nature of science processes/methods as discussed earlier.

This has a significant impact on student science learning itself. In addition to alternative concepts, students come to science instruction with naïve theories and/or misconceptions about the Nature of Science (NOS). These beliefs about science impact student understanding of the content knowledge itself (Lederman, 2007).

Seeking for improvement of science teaching in Europe

Next to others an EU expert group lead by Michel Rocard launched the Report 'Science Education Now a Renewed Pedagogy for the Future of Europe' in 2007 addressing the issue that there is a decline in the interests of young people for careers in Science.

Experts claim (ibid p. 7–11) that;

- science education is far from attracting crowds and in many countries the trend is worsening.
- the origin of this situation can be found, among other causes, in the way how science is taught.
- many on-going initiatives in Europe actively contribute to the renewal of science education. Nevertheless, they are often small-scale and do not actively take advantage of European support measures for dissemination and integration.

Accordingly the Rocard Report (2007) aims for bringing about a 'radical change in young people's interest in science and to identify the necessary pre-conditions' (p. 5).

Expert findings (p. 13–14.) suggest that;

- A reversal of school's science teaching pedagogy from mainly deductive to inquiry-based methods provides the means to increase interest in science.
- Renewed school's science-teaching pedagogy based on IBSE provides increased opportunities for cooperation between various actors in the formal and informal arenas.
- Teachers are key players in the renewal of science education. Among other methods, being part of a network allows them to improve the quality of their teaching and supports their motivation.

IBSE is assumed to increase young people's interest and attainment levels while at the same time stimulating teacher's motivation in teaching science. Two best practice models, the POLLEN and the Sinus Transfer project funded in FP6 and through German grants, are considered to have proven capable of increasing children´s interest and attainments in science. 'With some adaption', the authors argue, 'these initiatives could be implemented effectively on a large scale that would have the desired impact' (ibid, p. 14–15).

Although IBSE is a teaching approach to find favour with education policies and European funding schemes it is still not well defined and meanings associated with 'inquiry' are manifold (Capps & Crawford, 2013).

At almost the same time, a report to the Nuffield Foundation edited by Jonathan Osborne and Justin Dillon (2008) raised concerns about Science Education in Europe and offered critical reflections and several recommendations.

According to this report, the seven recommendations given that require addressing in the near future are:

1. To educate all students both about the major explanations of the material world that science offers and about the way science works. Science courses whose basic aims is to provide a foundational education for future scientists and engineers should be optional
2. More attempts are required to innovative curricula and ways of organising the teaching of science in order to address the issue of low students motivation.
3. EU countries need to invest in improving the human and physical resources available to schools for informing students both about careers in science and careers derived from science
4. EU countries' should ensure that teachers of the highest quality are provided for students in primary and lower secondary school and the emphasis on science education before 14 should be on engaging students with science and scientific phenomena (extended investigative work and hands-on experimentation is recommended)
5. Developing and extending the ways in which science is taught is essential for improving student engagement. Transforming teacher practice across the EU is a long term project and will require significant and sustainable investment in continuing professional development (CPD)
6. EU governments should invest significantly in research and development in the assessment in science education
7. Good quality teachers, with up to date knowledge and skills are the foundation of any system of formal science education. Systems to ensure the recruitment, retention and CPD of such individuals must be a policy priority in Europe.

Thus the authors put teachers, teachers CPD and development in science teaching at the centre of progress and stressed the fact that young children in primary and low secondary school in particular should get the best teachers. They focus on science being taught to all children, providing a response to the goal of all students becoming scientifically literate. It does, however emphasis the point that it is not a general aim that all student become scientists (Osborne & Dillon, 2008).

The Austrian teacher training system has recently followed this advice and a new teacher training law has been published asking all teachers from primary school upwards to attend a five year academic education process provided by at universities and pedagogical colleges. It will be important in the future that these training institutions put emphasis on science and technology education for teachers and require a fundamental and well devolved understanding of how to teach science content as well as science pedagogy to young children in particular.

Classroom practice in Europe

The recent OECD Teaching and Learning Survey, TALIS 2008, was carried out to fill the gaps in international data about teaching practices as well as the working conditions for teachers and the learning environments in lower secondary school. It surveyed 7,000 teachers and 4,000 school principals in 24 participating countries (Vieluf et al., 2012).

Three dimensions of classroom teaching practices were identified in TALIS 2008. These dimensions are 'structuring', 'student orientation' and 'enhanced activities'.

- 'Structuring' activities describe teaching practices which clarify the structure of a unit or lesson and its ultimate goals, as well as test whether all students have understood the content and performed their task
- 'Student orientation' activity concerns group work and adaptive instruction but also students participation in classroom planning

Both dimensions ask for practices that involve close interaction of the teacher with the whole class, small groups or individual students.

- 'Enhanced activity' does not include the latter but instead summarises practices that give students the chance to work independently over a longer period of time.

Key findings show that only a minority of teachers has a profile that demonstrates a comparatively diverse use of classroom teaching practices. Teaching practices are influenced by pedagogical traditions and national cultures, resulting in qualitative differences in the frequency of diverse teaching activities applied.

Professional development in Europe

According to TALIS 2008 findings the main driving-forces for advancement in teaching practice are;

- developing a larger repertoire of classroom teaching practices
- taking collective responsibility and
- working co-operatively to improve instructions.

Professional learning communities are assumed to be an alternative and even more successful way for the professional development of teachers in the long run. They provide the space for learners to discuss and exchange knowledge as well as make use of the social capital individual members provide (Hofman & Dijkstra, 2010).

TALIS 2008 investigate whether teachers participate in professional learning communities to develop their practice. Here the concept of a professional learning community is rooted in the socio-constructivist idea and in models of learning organisations mentioned earlier. Professional learning communities include 5 characteristics namely:

- co-operation among teachers (such as team teaching)
- holding a shared vision,
- having a clear focus on learning,
- practicing reflective inquiry and
- engaging in the de-privatisation of practice (e.g. work cooperatively to share their teaching methodology, issues and successes)

Exploring whether all these five dimensions of a Community of Practice (CoP) are being implemented, findings reveal that teachers in Europe hardly ever participate in professional learning communities. Large differences can be observed in the implementation of certain aspects that characterise communities of practice. Findings also revealed that 55% of the teachers participating in the TALIS survey wanted more professional development because they felt they needed more help around the topic of classroom management and working with special needs students. The larger the repertoire of teaching practices, the more tools teachers hold in their 'toolbox' (Vieluf et al., 2012). Professional development is a key to ensure that teachers have this full 'toolbox'. In the long run, teacher networks may provide an alternative and even more successful way to professional development of teachers. The network provides the space for learners to discuss and exchange knowledge, as well as makes use of the social capital individual members provide (Hofman & Dijkstra, 2010).

2.3.3 Inquiry Based Science Education (IBSE)

At the beginning of the 20^{th} century, 'Inquiry Based Science Learning`(IBSL) environments were already assumed to be fruitful ways to put cognitive theory and social-constructivist ideas into practice, as well as provide space for situated learning in a more 'authentic' science context (s.p. 23ff).

Educational theorists and psychologist such as Dewey, Schwab, Ausuble, Bruner and others have repeatedly asked for school science to become less didactic and trans-missive and less focussed on accumulating facts and procedures. Good science teaching was already presumed to be more effective if it explicitly included learning about the nature of scientific knowledge as well as inquiry-based activities.

However, implementing change in any educational system is a particularly slow process. Hence there is no wonder that the same ideas appear to be still extremely progressive today.

As the nature of scientific knowledge is situated, practiced and collaboratively generated a 'renewed' European science pedagogy is asking for the inclusion of more activities such as experimentation, trial and error, hypothesis testing, presenting, communicating and debating into everyday science teaching (Rocard, 2007). Lunetta and colleagues (2007) assume that there is a widespread agreement among scientists, policymakers, researchers, science teacher educators and presumably science classroom teachers, that students should experience inquiry in the science classroom or at LOtC institutions more often. It is assumed that the teaching of inquiry based learning will support student ability to meet 21^{st} century science education goals (s.p. 38ff)

What is Inquiry Based Science Education?

The inquiry based education movement has been strong in the United States of America for a couple of decades now and the National Science Education Standards have required the implementation of inquiry based learning in US science classrooms since 1996 already. Because of this science education research literature frequently refers to the US National Science Research Councils definitions for science inquiry in the classroom. Here 'inquiry' is defined as a science knowledge gaining process and is characterised by 'the diverse ways in which scientists study the natural world and propose explanations based on evidence from their work" (NRC, 1996, p. 23).

Referring to the NRC 1996 definition, Anderson (2002) argues that the term 'inquiry' is used:

1. to describe the many processes that professional scientists apply. The US National Science Education Standards stress the point that these non-linear, sometimes messy pathways, should not be confused with the formulaic method.

2. to describe the active learning process that students engage in modelled after the inquiry process of professional scientists. Harlen (2013, p. 12) assumes that using skills employed by scientists means to:
   - progressively develop ideas
   - make observations,
   - raise questions
   - examine books or other source of information,
   - plan investigations,
   - use tools to gather, analyse and interpret data,
   - use sufficient and relevant data for testing hypothesis
   - be rigorous and honest in collecting data
   - keep careful records throughout the investigations
   - repeat data collection
   - draw conclusions
   - review what is already known in the light of evidence,
   - propose answers, explanations and predictions
   - communicate results and share ideas.

In short, this process is described as:

> 'inquiry' is content in and of itself: a process about which students should learn and in which they participate. The standards clearly spell out though, that inquiry is more than a process, more than something students should do. It is a vehicle for learning science content. The second definition of inquiry in the standards refers to specifically designed experiences and activities that lead to knowledge and understanding of scientific ideas and content'. (Asay & Orgill, 2009, p. 58)

Daphne Minner and colleagues (2010) add a third point to Anderson's definition arguing that the term inquiry also applies to;

3. the pedagogical approach that teachers employ when designing or using curricula that allow for extended investigations.

A variety of terms are used in Europe to talk about inquiry-based approaches in science learning. Inquiry Based Science Learning (IBSL), Inquiry Based Science Education (IBSE) or Inquiry Based Science Teaching (IBST) are often used synonymously in various contexts. The situation becomes even worse whenever the term is translated. In German for example IBSE is translated as "*Forschendes Lernen*" which neither offers a reference to "*Bildung*" (education) nor to inquiry 'based' which means '*sich orientieren an*' oder '*aufbauend auf die Naturwissenschaften*' (science based).

In everyday German '*forschen*' is mainly used in the context of research, which may lead to confusing '*Forschendes Lernen*' with 'what scientists really do'. So in the German context I prefer to use the term *'Forschungsorientiertes naturwissenschaftliches Lernen'*. This literally refers to 'inquiry based science learning'.

Inquiry Based Science Teaching

In this monograph I will refer to the NRC´s definition of IBSE presented above and will use the term Inquiry Based Science Teaching (IBST) to make explicit that I am talking about a variety of pedagogical approaches that teachers or LOtC educators employ to supports inquiry based science learning either in class or outside the classroom. These various approaches to inquiry instructions makes it difficult to get a clear picture about what students actually gain from IBST based learning environments and whether the learning lives up to proposed expectations (Minner et al., 2010). So far there is evidence that good IBST provides opportunities for students to:

- Learn meaningfully (Kubicek, 2005)
- Learn about the nature of science and develop scientific ways of thinking (Bianchini & Colburn, 2000, Caps & Crawford, 2013)
- Develop a better understanding of content knowledge (Minner et al., 2010)
- Develop the ability to evaluate scientific data and models (NRC, 2001)
- Overcome pre-existing misconceptions (NRC, 2001)
- Are often motivated to learn about science (Palmer, 2009)
- Develop positive attitudes towards science (Brown, 1996)

Minner, Levy, and Century (2010) argue that inquiry teaching has essential features which should be applied and which are described by the NRC (1996; and 2000, p. 25) as following:

- Learners are engaged by scientifically oriented questions
- Learners design and conduct investigations
- Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions
- Learners formulate explanations from evidence to address scientifically oriented questions
- Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding
- Learners communicate and justify their proposed explanation

However, the US National Science Education Standards make a distinction between full and partial inquiry. In full inquiry all of the essential features are present, whereas in partial inquiry only some of the essential features mentioned above can be observed. Research has shown that a full inquiry process is almost never applied (Asay & Orgill, 2009) and

> [. . .] that there was no statistically significant association between amount of inquiry saturation and increased student science conceptual learning. However, subsequent model refinement indicated that the amount of active thinking, and emphasis on drawing conclusions from data, were in some instances significant predictors of the increased likelihood of student understanding of science content (Minner et al., 2010, p. 493)

These findings raise the question whether active thinking and decision making needs to be embedded in a full inquiry cycle or might be equally effective when applied outside the investigative context.

> [Research on] this kind of work could significantly help practitioners with limited time and resources determine when to increase the emphasis on active thinking or responsibility for learning (decision-making) in their science teaching. (Minner et al., 2010, pp. 493–494)

Inquiry Based Science Learning

Barron and Darling-Hammond (2010) use the term 'inquiry based learning' to describe a 'family of approaches', which include project-based learning, design based learning and problem based learning. Asay and Orgill (2009) provide multiple research-based evidences that teachers are equally uncertain about the term 'inquiry'. Some describe inquiry as discovery learning ('Entdeckendes Lernen'), project based learning, hands-on learning, authentic problem solving, classroom discussions, and debates while others equate inquiry learning with an increased level of student direction allowing students to ask their own questions, to determine which data to collect or to design procedures.

For others, inquiry learning is sometimes seen as an unstructured and unguided student centred approach to learning (Mayer, 2004; Kirschner et al., 2006). Morrison (2013) explored elementary teachers conceptions about inquiry and found that teachers frequently hold ideas about inquiry, such as it is all about 'finding things out' or 'exploring and experimenting with things around us'.

Recent findings indicate that the majority of teachers surveyed (n = 26!) held limited views of inquiry based instruction and these views were reflected in their teaching practice. Most commonly, teacher's focus on the basic abilities required for inquiry instead of the essential features or important understanding about inquiry (Capps & Crawford, 2013).

Different views on inquiry learning are based on different views of 'science inquiry', 'science learning' or 'attitudes towards students and their ability to learn science'. It is also widely accepted that teacher beliefs about teaching, learning and the nature of science can influence their practice (Hogan & Berkowitz, 2000). Elementary teachers in particular have limited understanding of the subject matter and also often have weak pedagogical content knowledge that they can apply to support inquiry based learning (Appleton, 2007).

In addition, there is disagreement about the various ways that these learning processes can be facilitated and the degree of structure that needs to be provided by the teacher. Minner, Levy and Century (2010, p. 476) found that 'classroom inquiry shows varying degrees of direction or instruction given by the teachers and these distinctions are often poorly articulated by scholars and practitioner alike'.

However, the amount of direction and decision-making applied by the teacher versus the student is known to be particularly influential to students learning. The scope between open and guided inquiry, and the role scaffolding plays in students learning outcomes have been frequently discussed in literature. (Hmelo-Silver et al., 2007; Wichmann & Leutner, 2009; Kirschner et al., 2006; Mayr, 2004)

The term 'scaffolding' is used to define a particular way of providing help to the learner. This support is tailored to the learners needs in achieving his or her goals at any one moment. Scaffolding should also build on itself at the pace of the student. The best scaffolding provides help in a way that contributes to learning; effective scaffolding provides prompts and hints that help learners to figure issues out themselves. It supports student's active construction of knowledge (Wichmann & Leutner, 2009).

> ‚Precisely the lack of shared understanding of defining features of various instructional approaches has hindered significant advancement in the research community on determining effects of distinct pedagogical practices' (Minner et al., 2010, p. 476)

New curriculum initiatives, focused on inquiry using complex instructional strategies, were found to promote significant increase in learning among students more often. These effects, however, were not always sustained as curriculum reforms were scaled up and used by teachers who did not have the same degree of understanding or skill in implementation (Barron & Darling-Hammond, 2010).

When is Inquiry Based Science Teaching effective?

Research has shown that different formats of instruction are suitable to different learning outcomes and some formats seem to be more effective than others.

Good IBS teaching is assumed to include formats such as:

- students are expected to come up with high quality performance/presentations and teachers provide guidance and feedback about the process and the quality of student's work (Barron et al., 1998)
- outcomes are evaluated and learning is repeatedly assessed; self and teacher assessment (Harlen, 2013)

- students are asked to think about possible solutions of a problem first e.g. formulate hypothesis (Schwartz & Martin, 2004)
- iterative cycles of reflection and action are applied and opportunities to learn from experience and feedback are provided
- learning activities include teamwork and collaboration as well as small and large group discussions (Barron & Darling-Hammond, 2010)
- Emphasis is put on active thinking and on drawing conclusions from data to increase student understanding of science content (Minner et al., 2010)

Classroom research indicates that well designed carefully thought out materials and connected classroom practices are needed to capitalise on inquiry approaches. Without careful planning, students may miss opportunities to connect their work with the key concepts underlying a discipline (Petrosino, 1998).

Authentic problems and projects afford unique opportunities for learning but authenticity in and of itself does not guarantee learning (Barron et al., 1998, Thomas, 2000). Thus providing students with rich resources and an interesting problem are not enough. Students need help to understand the problem, as well as support in how to apply science knowledge, how to evaluate their experimental or other inquiry based designs, how to explain failures, and how to engage in revision. In addition they need to be explicitly prompted to use information resources. Teachers are expected to scaffold, not to impose participation structures and classroom norms that encourage accountability. By scaffolding teachers admonish students to use evidence, take a collaborative stance and reflect critically on their findings (OECD, 2012).

When designing co-operative group work teachers should pay careful attention to various aspects of the work processes and to the interaction among students. Slavin (1991) argues that it is not enough to simply tell students to work together. They must have a reason to take one another's experience, opinions, findings and arguments seriously. Therefore teachers should consider setting group tasks with structures promoting individual accountability.

In addition the teacher plays a critical role in establishing and modelling practice for productive learning conversations. In doing this successfully he/she supports students to improve their social and behavioural skills, self-concept, academic outcomes and their ability to concentrate on the task. Observing group interaction carefully can provide substantial amount of information about the degree to which work is productive. Johnson and Johnson summarised 40 years of work on co-operative learning and came up with basic elements that are important across a range of different models and approaches. These are positive interdependence, individual accountability, structures that promote face to face interaction, social skills and group processing (Barron & Darling-Hammond 2010).

Teachers need to apply well designed formative and summative assessment to not only support students learning but to become more proficient in designing an inquiry base learning environment themselves (OECD, 2012). Collaborative and inquiry approaches to learning require that we consider classroom activities, curriculum and assessment as a system in which each interdependent aspect is essential to provide a learning environment that will promote robust learning. Indeed, teacher's ability to assess both formatively and summatively has enormous implications for what is taught and how effectively this is done. Research suggests that thoughtfully structured performance assessment can support improvements in the quality of the teaching (Barron & Darling- Hammond, 2010).

Formative assessment is assumed to create fundamental changes in teacher's abilities to teach effectively.

> 'As [teachers] use assessment and learning dynamically, they increase their capacity to derive deeper understanding of their student's response; this then served to structure increased learning opportunities" (Darling Hammond, Ancess & Falk 1995, as cited in Barron & Darling- Hammond, 2010, p. 210).

Thus formative assessment not only helps the student to monitor their learning process but assessment outcomes provide teachers with evidence to critically reflect on their own performance.

> 'All assessment of students' achievements involves the generation, interpretation, communication and use of data for some purpose. In just this simple statement there is room for an enormous range of different kinds of activity, but each will involve a) students being engaged in some activity, b) the collection of data from that activity by some agent, c) the judgement of the data by comparing them with some standard and d) some means of describing and communicating the judgement. There are several forms that each of the components of assessment can take (Harlen, 2013).

Currently, science education research does not provide a straight-forward operating procedure in IBST that has proven to be consistently effective (Minner et al., 2010).

However, the following basic feature are frequently named as important characteristic;

Science inquiry is always based on natural phenomena and is expected to give answers to scientific questions only. E.g. scientists may not be able to answer a question such as 'why is the sky blue?' but can answer 'how does it happen that the sky appears blue?'

A scientific question, either one triggered by student curiosity or by the teacher is commonly seen as a starting point for classroom/LotC inquiry.

A particular observation or demonstration can be used to promote these questions. The 'quality' of the question is strongly related to the number of learning opportunities the particular learning environment offers (Crawford, 2000).

To articulate possible answers to the question, based on pre-existing knowledge, is the next step assumed to be crucial for developing a deeper understanding of the phenomenon. Existing beliefs are considered important in a conceptual development process. While possible explanations or hypothesis are formulated pre-existing concepts are made explicit. A hypothesis will also lay the foundations for the following data collection process.

Data could be collected via an experimental design, observation, literature research, interviewing experts, exploring a LOtC site and taking notes etc. Different phenomena or questions require different approaches to collecting evidence.

Collected data needs to be analysed and conclusions need to be drawn from this data. This one and the following steps are assumed to be most important in a successful inquiry process.

Next the outcomes are presented and discussed in groups of any chosen size. Finally the knowledge gained is challenged by the students and the teachers in the light of their own or expert knowledge. Expert knowledge can be available in person (e.g. at a LOtC site) or via a thorough literature research. Final conclusions are expected to be consistent with currently broadly accepted scientific understanding (Asay & Orgill, 2009, Minner et al., 2010, Capps & Crawford, 2013).

In short the presence of a scientific content, various types of science related student engagement and components of instruction, which emphasise student responsibility for learning and decision making (e.g. to decide which question to investigate, to identify where and when help is needed in developing the design, to decide on how to organise data, draw and discuss conclusions, to decide on how to communicate results) is essential (Minner et al., 2010). In addition, learners should be asked to critically evaluate what they read and are expected to express themselves well both verbally and in writing. Knowledge generated by students that is usable and integrated in everyday experience should be favoured over compartmentalized and contextualised knowledge of facts and procedures. Collaboration and conversation amongst students is critical because it allows the learner to benefit from the power of articulation. Articulation is most effective when scaffolded. When learners externalise and articulate their developing knowledge they learn more effectively. The best learning takes place when learners articulate their unformed and developing understanding and continue to articulate it throughout the learning process. Articulation and learning are a mutually reinforcing feedback loop. While thinking out loud learners learn more rapidly and deeply than by studying quietly. Articulation makes reflection (thinking about the process of learning) and metacognition (thinking about knowledge) possible and reflection has been proved to deepen understanding (Sawyer, 2006, 2008).

Last but not least the concept of the nature of science needs to be made explicit throughout the whole inquiry process. Although it is commonly expected of students, they do not necessarily understand the nature of science whilst doing science. The rational of why science is done in a particular way needs to be addressed (Sadler et al., 2010). Last but not least learners should be asked to apply and understand mathematics in various aspects of science inquiry (Capps & Crawford, 2013).

IBSE challenges teacher's professionalism

To assist teachers in their implementation of inquiry based learning various models have been developed, discussed, favoured and dismissed within the last two centuries of IBSE history. Following these discussions it becomes increasing obvious how both critical and challenging it is for teachers to plan and enact inquiry based instructions. According to Roehring and Luft (2004) four factors have a crucial impact on teacher's performance;

Factor 1) Science content and pedagogical knowledge:
Science teachers who implement inquiry based instruction need to understand the prominent concepts in their discipline. Knowledge that is fragmented or compartmentalized does not help teachers to craft instructions that best represent inquiry. Teachers need a deep and highly structured content knowledge base. In biology, teaching this becomes particularly challenging because prominent concepts of the discipline are constantly evolving and developing. In addition teachers need to understand the principles of IBST in very detail to become effective in scaffolding student learning.

Factor 2) Individual views of the Nature of Science:
Supporting young people to understand the Nature of Science is a central aim in modern science education. However teachers hold a wide variety of beliefs about the nature of science and need to reflect on their personal understanding first in order to later scaffold 'authentic' science learning experiences effectively. Thus teachers need to reflect on ccommon assumptions and need to address them explicitly when a particular scientific approach is applied.

Factor 3) Individual views of teaching science
Teachers often hold very personal views of teaching, their students confidence to achieve tasks, subject matter and student learning etc. These beliefs about teaching and learning have a strong impact on teacher classroom practice (Fang, 1996). Research has shown that teachers that hold a more positivist view of science tend to hold a trans-missive view of teaching, whereas those holding a more contemporary view of science knowledge are more likely to espouse a constructivist view of learning (Pope & Gilbert, 1983)

Factor 4) Changing roles in learning
In inquiry based practices teachers and students have to fulfil different roles compared to traditional classroom practices. These changes need to be made explicit for those enacting them – students and teachers alike. E.g. students need to feel responsible for their own learning and teachers need to be confident that their students are capable of doing that.

None of these factors were found, in isolation, to be predictive of the quality of the implementation of inquiry based instructions, because the interplay of these factors makes the difference. Factors work collectively, in different degrees, to influence instructions. Holding a contemporary view of the nature of science is necessary, but not sufficient, to implement inquiry based lessons. However, novice teachers with a contemporary view of science are more likely to implement inquiry lessons in their curriculum. Teachers who hold student centred beliefs are also more likely to implement Inquiry in their classroom. Content knowledge alone does not guarantee the implementation of inquiry based lessons, however, strong content knowledge combined with a student centred belief and a contemporary view of the nature of science increases the likelihood that inquiry is implemented in the classroom (Roehring & Luft, 2004)

Inquiry based science teaching has been a buzz-word in Europe since the Rocard Report was published by the European Commission in 2007. However,

> 'there is still no consensus as to what it [inquiry based teaching] actually is and what it looks like in the classroom (Anderson, 2002)`. If the academic community has not reached consensus, how can we expect teachers to understand what inquiry is and how to teach science in this way?' (Capps & Crawford, 2013, p. 523).

So far science education research does not provide one straight forward operating procedure that has proved to be the most effective way to support student learning. It is still teacher's responsibility to find out whether their IBST approach is efficient in achieving desired learning outcomes. However, we will see later that this uncertainty has a great potential to challenge practitioners and science education researchers to 'cross boundaries' and to initiate expansive and collaborative learning processes which finally will 'renew science pedagogy in Europe'.

2.4 Alternative Places for Learning Science

2.4.1 Learning Outside the Classroom (LOtC)

> *All learning takes place in settings that have particular sets of cultural and social norms and expectations and that these settings influence learning and transfer in powerful ways (National Research Council 2000)*

More than any other species, human beings are designed to be flexible learners and, from infancy, are active agents in acquiring knowledge and skills (Donovan & Bransford, 2005). In doing so, learning is not restricted to formal education institutions like schools, colleges or universities, but also occurs beyond the classroom (Bentley, 1998).

Visiting institutions such as science museums, science centres, botanic gardens, zoos or aquaria in a school based context offers learners a wide range of learning options and the opportunity to explore what is interesting for each individual learner. These places provide authentic experiences using real objects and, particularly in zoos, aquaria and botanical gardens - living organisms (Wellington, 1998, Falk & Dierking, 2000).

In the international context, the use of places other than the classroom for teaching and learning is termed "Learning Outside the Classroom" (LOtC). Institutions providing learning experiences for school classes or student groups are therefore included under the title banner of 'LOtC institutions' (LOtC) in this work. The Council for Learning Outside the Classroom website (http://www.lotc.org.uk/) provides a comprehensive summary of sites which can be used for learning outside the classroom. From a qualitative perspective, however, one has to admit that all these various learning environments offer very different opportunities for learning and the quality of the learning experience in each individual LOtC setting may differ, in the same way that it differs with learning science in any classroom.

An Ambivalent Attitude towards Learning

According to the 'Science Center World Congress', over 310 million people actively participate in engagement programmes organized by over 2500 science centres in more than 90 countries annually (Hein, 2012). These institutions include a variety of places such as traditional museums, natural history museums, historic houses and outdoor centres (e.g. national parks), and heritage and botanic gardens. While new places for learning are emerging constantly, traditional institutions such as Museums, Botanic Gardens or Zoos have dramatically progressed by embracing an educational role.

In 1992 the American Association of Museums proposed:

> 'a new definition of museums as institutions of public service and education, a term that includes exploration, study, observation, critical thinking, contemplation and dialogue' (AAM, 1992, cited in Hein, 2012, p. 178)

While some authors claim that a 'paradigm shift' has taken place, changing museums, zoos and botanic gardens from old fashioned, inward looking institutes with collection of objects into educational institutions committed to serve divergent audiences, others, including those working alongside Botanic Gardens are more cautious.

Hein (2012) argues that:

> ‘the concept of museums as institutions in the service of the public is as old as the museums themselves. Conversely, during this same period and continuing today there are museum professionals who consider education to be a secondary function of museums with collection and preservation of cultural objects being their primary concern. . . . And others have always incorporated a vision of progressivism into their practice, both pedagogically ant politically’ (p. 179).

Taking the history and the current status of botanic gardens into consideration, the tension between those persons viewing such institutions as primarily educational and those seeing the role as preservers and collectors of living species is not likely to disappear in the near future.

> ‘However since there is still evidence that education is still not recognized as equal to curatorial activity in many museums (including botanic gardens). I doubt that we will see a true paradigm shift in any time soon (Hein, 2012, p. 179).

It’s not only the case that the LOtC institutions themselves place education and learning as a secondary activity. Many teachers still conduct visits to LOtC´s as ‘add on´s’ rather than as ’add in´s’ to their teaching agenda, treating them merely as a ‘nice day out’, even though research has shown that best learning results can be achieved when LOtC learning is integrated with the everyday school curriculum (Cox Petersen, 2003).

The Potential of LOtC Learning

Research shows increasingly clear data that learning outside the classroom (LOtC) is associated with several positive outcomes for students such as more engagement in learning and higher levels of academic achievement. (Dillon & Osborne, 2007; Dillon, 2007; Rickinson et al., 2004). The “Committee on Learning Science in Informal Environments” comprised of 14 experts from the fields of science, educational psychology, media and informal education conducted a broad review of the literature that is related to learning science in informal settings and published their outcomes in 2009 (Bell et al., 2009). The committee found abundant evidence that across all venues individuals of all ages learn science. LOtC sites are good in that they provide the space for life-long learning experiences with science, have the potential to support systematic learning and reliable knowledge about the natural world as well as the development of important skills for learning science. They are rich with real world phenomena and are therefore places where people can pursue and develop science interests, engage in science inquiry and reflect on their experiences through articulating their views in conversation with others. Structured, non-school, science programs which include sustained self-organized activities for science enthusiasts can feed or stimulate interest in science in both adults and children and may positively influence academic achievement for students. These programmes may also expand the participant's knowledge of future science career options (Bell et al., 2009).

Rickinson and colleagues (2004) concluded that:

> 'Fieldwork can have a positive impact on long-term memory due to the memorable nature of the fieldwork setting . . . it can lead to individual growth and improvements in social skills. More importantly, there can be reinforcement between the affective and the cognitive, with each influencing the other and providing a bridge to higher order learning. . . . There is significant evidence that social development and greater community involvement can result from engagement in school grounds projects. Students develop more positive relationships with each other, with their teachers and with the wider community through participating in school grounds improvements` (p. 24).

Phillips and colleagues (2007) survey, with 475 science oriented LOtC institutions in the United States of America, confirms these assumptions. Authors conclude that LOtCs do have a great potential to support K 12 (pupils between 5–18 years) science education.

Many practitioners, researchers and educational policy makers already recognise the potential of learning experiences provided in a LOtC setting. The 2007 European Rocard report 'Science Education Now – A renewed pedagogy for Europe 'explicitly mentioned LOtCs as potential partners for implementing inquiry based science education on a large scale in Europe. The UK government recently introduced a new education Manifesto, 'Learning Outside the Classroom', which acknowledges the wealth of research on the impact and benefits on children's learning using 'out of classroom' approaches. (LOTCM, 2007). The National Educational Standards in the USA calls attention to the potential science museums have to foster student interest in science and to support student understanding of science. The Austrian Science Center Network was founded in 2006 and currently joins more than 130 partners contributing actively to the community by developing, offering or using interactive science centre activities. (for more information see: http://www.science-center-net.at/index.php?id=238)

In Austria, 90 % of the schools which participated in the PISA 2006 assessment use excursions and LOtC visits to support student engagement in science.

Additionally, 70% of schools ask their students to learn about environmental issues not only in class but in nature reserves, museums and science and technology centres (Grafendorfer & Neureiter, 2009).

The LOtC Science Learning Environment:

According to Bell, Lewenstein, Shouse, and Feder (2009) science oriented LOtC sites have the potential to create learning environments, which provide the quality and the space for fruitful science learning. Visiting these places one expects that students will be able to:

- experience the excitement, interest and motivation to learn about phenomena in the natural world
- generate, understand, remember and use concepts, explanations, arguments models and facts related to science
- manipulate, test, explore, predict, question, observe and make sense of the natural and physical world
- reflect on science as' a way of knowing', on processes, concepts and institutions for science and on their own processes in learning about phenomena
- participate in scientific activities and learning practices with others, using scientific language and tools
- think about themselves as science learners and develop an identity as someone who knows about, uses and sometimes contributes to science.

'Thus learning at science oriented LOtC sites is distinct from, but overlaps with, the science specific knowledge, skills, attitudes and dispositions that are ideally developed in schools' (ibid, p. 4).

However, learning environments created in science oriented LOtC institutions are very diverse in nature and this diversity is enhanced when educational managers, school liaison officers, communication assistants, guides, explainers, wardens, museum teachers, botanic garden educators, rangers etc. are asked to support and facilitate the learning processes taking place in workshops or in any other kind of on-site engagement with visitors. In this paper I will refer to these people as "educators" going forward.

Peacock and Pratt (2011) summarised a number of additional factors that impact on the quality of these environments, namely:

- The physical layout, structure, design and collections on display in the garden or the building. This can either distract (e.g. museum shop, narrow paths, etc.) or support learners (e.g. glasshouses, carnivorous plants, good group gathering places, availability of seminar rooms, outdoor setting etc.) to focus on explicit learning objectives.

- The socio-cultural background of all participants (e.g. teachers, students, educators participating in a workshop etc.). Also their perception of this particular learning environment, their related experiences (personal history) as well their perceived significance of the learning goals and the artefacts presented in this context (e.g. 'exciting versus boring plants')
- The learning activities afforded and the constraints of physical arrangements, social groupings, accessibility and localised distractions.
- Tension between the conflicting agendas of all the stakeholders responsible for running the site e.g. funding bodies, University boards, interpretation and exhibition designers, scientists, visitor services and educators as well as the approaches to learning in such a context by teachers, students or any visitors.

The field trip learning environment

The term 'learning environment' is usually applied in educational literature to any setting in which learning takes place. This term is even more appropriate in the context of learning at botanic gardens, zoos, national parks or outdoor centres, because the word 'environment' has a specific contextual meaning in such sites and is used regularly in their educational programmes. Learning in and about a 'living or natural environment', as well as 'environmental education' are often key priorities.

Thus a context related learning environment is created whenever teachers take their students on field trips to outdoor LOtC settings where they may or may not ask locally based educators for support.

In their review of literature, DeWitt and Storksdieck (2008) argue that a substantial body of research has been accumulated on fieldtrips over the past 30 years which has provided evidence that, from the perspective of cognitive and conceptual learning outcomes. . . .

> '. . . under certain favorable circumstances, fieldtrips may lead to somewhat better learning outcomes than school based instructions' (p. 181).

Anderson, Lucas, Ginns, and Dierking (2000) report on a great deal of research that has been done to assess the cognitive effects of class visits to outdoor settings. E.g. educational programs associated with parks have proven to enhanced environmental stewardship, environmental attitudes, knowledge about the natural world, and positive attitudes toward the parks.

Sellemann and Bogner (2013) recently reported evidence that learning about climate change at a botanic garden has a significant increase of 'knowledge scores' in a post visit test and that this score showed no decrease in a retention test, which was taken 4–6 weeks after the event. While some research results suggest that school based instructions might provide 'more learning per unit' additional outcomes, such as process skills or awareness of life- long learning community infrastructures, have been reported.

Besides increased cognitive learning, field trips provide positive affective and social experiences. Gains in motivation or interest, sparked curiosity or improved attitudes towards the topic are visible.

> 'Learning on and from a field trip, hence, is no longer seen as simply an extension or improvement of classroom teaching, but as a valuable supplement and addition to classroom instruction, as well as an excellent way to prepare students for future learning' (DeWitt & Storksdieck, 2008, p. 181).

Field trip learning can be a valuable supplement and addition to classroom instructions as well as an excellent way to prepare students for future learning (Storksdieck et al., 2006). The effect of field trip learning is unique for its long-term impact. Various scholars have emphasized that individual learning may appear or come to maturity a long time after the experience has ended. Even 16 months after the visit, students were still able to recall names of exhibits, remember activities they did and were able to refer to guide explanations. (Bamberger & Tal, 2008). Bertsch, Unterbruner and Kapelari (2008) showed that the cognitive knowledge gained by primary students in a field trip based 'school - botanic garden' project did not decrease during the 6 months following the close of the project.

However, students appear more likely to remember social and personally relevant aspects of a field trip; however they unfortunately also retain less favourable memories of fieldtrips such as those trips that seemed overly structured and left little room for their personal agenda (DeWitt & Storksdieck, 2008).

Factors which impact fieldtrip learning

Field trips have the potential to live up to the expectations for science learning as mentioned above, but are very much influenced by a complex set of individual, situational, social and historical factors which may limit, as well as enhance, science learning. These dependencies have to be reflected on and made visible in order to understand how a field trip learning environment can contribute most effectively to a learner's development. The field trip setting as such might not be a guarantor for success. DeWitt and Storcksdieck (2008) argue that:

> 'Fortunately for many concerned with the outcomes of field trips, research indicates that both cognitive and affective learning can occur as a result of class visits to out-of-school settings and surrounding experiences, but such learning is fundamentally influenced by a number of

> factors, including the structure of the field trip itself, setting novelty, prior knowledge of the students, the social context of the visit, teacher agendas and actions on the field trip, and the presence or absence and quality of preparation and follow-up experiences' (p. 182).

Learner's individual perception of the environment:

Peacock and Pratt (2011) state that it is possible to distinguish different ways in which individual people comprehend terms or ideas, and how they respond to a particular environment. The latter may range from those who strongly identify with it to those who strongly reject it. With regard to botanic gardens in particular, the term 'natural environment' can be perceived in very different ways. Whilst an ecologist or environmentalists would never use the term in a botanic garden context, visitors often refer to botanic gardens as being 'a natural environment' because it is an open space full of living organisms.

The physical quality of a field trip learning environment is based on people's ability to make sense of the environment because the learning experience is highly situated within this physical environment. Sense making influences the transferability of knowledge and subsequent learning, as well as its long-term impact (Bamberger & Tal, 2008).

Relating science content to personal experiences is assumed to foster lifelong learning (Eylon, 2000). The physical setting of a botanic garden or any other outdoor learning space facilitates this process by taking real objects from real life and presenting them in a scientific context. Over and above the novelty of the fieldtrip setting has an influence on students' conceptual and possibly affective learning. Irrespective of whether the novelty of the environment is either very strong (because students never have been at the botanic garden before) or altogether absent (because students visit the place on a regular basis) new perspectives might be mitigated through giving a particular orientation to the trip prior or during the visit (DeWitt & Storksdieck, 2008).

Pre-existing knowledge

Interviews with children after their visits revealed that an important determinant of what students learn during engagement with artefacts is the knowledge they bring with them, often from their personal lives rather than from previous experiences in school (Peacock & Bowker, 2009; Österlind, 2005; DeWitt & Storksdieck, 2008; Blum et al., 2013).

This impact of prior knowledge on conceptual learning is well documented in the formal as well as in the LOtC or informal learning environment (Krüger, 2007; Falk & Storksdieck, 2005; Bell et al., 2009).

In addition student's individual interest in the topics they are engaged with as well as their own and their teacher's motivations and agendas shapes the learning on the field trip (Bell et al., 2009; DeWitt & Storksdieck 2008).

Social interaction

Social interaction includes both the interaction within and outside the small group a learner is working with. Sharing discoveries and experiences with others is assumed to support learning. Working in small student groups whilst on site allows students to ask more questions, do more hands-on work or just generally become more involved in the programme of activity (Price & Hein, 1991). The characteristics of the small group (e.g. gender balance, expertise and interest of members etc.) an individual learner is working with, may additionally shape the learning (Bell et al., 2009; DeWitt & Storksdieck, 2008).

According to studies done by Cox-Petersen and colleagues (2003) and Tal and colleagues (2005) a considerable amount of interaction is taking place, not only amongst the students themselves but also between the museum educator and the students. Less interaction is observed between teachers and their students. Österlind (2005) argues that pupils may not learn from each other and conversations between pupils about the content of the activity are sparse. In terms of conceptual development, the interaction between the pupil and the teacher respectively the educator or the pupil and the textbook (e.g. museums guide, or additional written information) seems to be more fruitful.

Based on their review of literature and the meta-analysis done by others such as Rickinson Dillon, Teamey, Morris, Choi, Sanders, and Benefield (2004) as well as Peacock and Pratt (2011) argue that field trip learning environments include factors which are not apparent in classrooms. In a fieldtrip setting Vygotsky's theory of mediated action (educator/teacher – child – object, see p. 31) has a different quality to that achieved in classroom learning. The field trip environment potentially allows children to interact with a wider range of adults (including scientists or museum educators) as well as a wider range of physical and mental 'objects' (e.g. living organisms, hands-on exhibits, group discussions etc.).

The fieldtrip structure

Although the impact of the program structure is assumed to be an important factor for learning from school field trips, the degree of structure has been debated in literature.

Some authors argue that guided tours or specific attention focusing devices (e.g. compulsory tasks, worksheets, textbooks etc.) may increase cognitive learning, others that overbearing structures diminish interest in the learning outcomes or positive attitudes toward the visit (Österlind, 2005; DeWitt & Storcksdieck, 2008). Because of this, highly structured field trips are often criticised for adopting a class-room style and task oriented approaches, which focus pupils on the process of 'schooling' (Peacock & Pratt, 2011, Adams et al., 2008).

For example, the values of worksheets, which are still popular with LOtC school-visit programmes are seriously questioned by Griffin and Symington (1997). Authors argue that worksheets require children to behave like school pupils with the associated goals that this entails, such as accuracy and completion of tasks. In this way, they seriously narrow the student's focus to only fill in or tick those boxes the worksheet requires. Carli (2013) reported a case study carried out at the University of Innsbruck Botanic Gardens in the course of the INQUIRE project. Interview outcomes revealed that when students used a worksheet for their insect observations in the garden they predominately answered the question: 'Why do you observe these insects?' with ' because we have been told to do so'. Scarcely any child responded appropriately to the initial purpose of the activity which was to find out 'why insects visit flowers'. Peacock and Pratt (2009) argue that their own studies reveal similar results.

However, both teachers and students feel that learning can be supported with well thought-out worksheets and that they can be highly productive in promoting discovery- and an inquiry style field trip experience (Kisiel, 2003). Therefore, they should not be dismissed out of hand, but those responsible for developing them, need to be aware that worksheets applied in a fieldtrip setting should:

- encourage observation
- allow time for observation
- refer to objects rather than labels
- be unambiguous about where information might be found
- encourage talk amongst group members (DeWitt & Storksdieck 2008, p. 186)

The use of worksheets is a norm presumably based on an educator's individual experience, either through their own education or during their teacher training sessions either on or off site. So the institutional history, as well as the cultural history, of educators who choose particular LOtC learning environments may need to be reflected on, particularly because they may be perceptually 'similar' to school learning.

Different cultures of learning

The situation mentioned above highlights another factor that should be considered in field trip learning environments – the tension between the two cultures of learning; this may or may not be obvious for either the teachers or the museum/ botanic garden educators.

Field trip learning environments bring together two different cultures of learning – the formal, classroom based learning and the out of school learning, sometimes referred to as 'informal learning' (Bell et al., 2009). Phillips, Finkelstein, and Wever-Frerichs (2007) argue that this fusion may blur the quality of learning outside the classroom. As long as 15 years ago, Griffin and Symington (1997) were already arguing for a move from task oriented to learner oriented strategies for field trips. According to Tal, Bamberger, and Morag (2005) 100% of school visits to museums in Israel are guided by a site-based educator. At

Innsbruck Botanic Gardens a maximum of 10 out of 150 school classes visit the garden annually without booking any activity programme offered by garden educators. When designing and organising fieldtrips or LOtC visits, it is the priority of both teacher and educator alike to explicitly understand the quality of learning outside the classroom if they want to support their students to get the most out of it.

The teacher's role

Teachers are the key decision makers in planning and implementing field trips and they play an important role both directly and indirectly in their students' appreciation of LOtC sites as places for learning.

From a socio-cultural perspective, teachers knowledge about, as well as their personal attitude towards LOtC learning is a product of historical, cultural and social backgrounds. These naturally influence the decision of whether a teacher takes his or her students on field trips or not and, if he or she does, how these field trips are structured, organised and what final learning outcomes are set.

Often not only teachers but head-teachers and even parents attempt to impose the same rules, goals, processes and cultural norms, which are operative in a classroom on off-site settings. These include notions of what constitutes school work, curriculum pressures and concerns about the effective management of students' time and behaviour. Rebar (2012) argues that a teacher's individual field trip experience as a student as well as their recent experience as a field trip leader, serve as models for later excursions. So teachers pre-visit agendas directly influence their own behaviour and expectations about the LOtC learning experience (Falk et al., 1998). According to Bamberger and Tal (2008), teachers in Israel often conduct field trips because the Israeli Ministry of Education acknowledges and appreciates LOtC learning experiences. They fund a large number of such institutions and money is allocated according to the number of student visits and the educational programmes offered. As a result Israeli teachers who organise field trips believe that LOtC learning is a highly valuable educational experience for their students, stimulating interest and motivation in science and developing scientific and social skills (Michie, 1998; Anderson & Zhang, 2003; Bamberger & Tal, 2008).

Falk, Moussouri, and Coulson (1998) discovered 6 key reasons why visitors to go to a museum, which are:

- the place is recognized as a leisure/recreational/cultural destination
- the educational aspects related to the aesthetic, informational, or cultural content of the museum is considered important
- it is a familiar, repeated activity that takes place at certain phases in one's life (e.g. parents taking their children because they experienced museum visits as children themselves)

- the visit is seen as a social event, as a "day out" for the whole family/ friends/ the class which provides the chance for individuals to enjoy themselves separately and together
- fun and enjoyment of going there in one´s free time and/or see new and interesting things in a relaxing and aesthetically pleasing setting.
- practical external factors such as weather, proximity to the museum, time availability, crowd conditions, and the entrance fee contribute to many visitors' decision-making process.

Kisiel's (2005) study revealed several similarities between visitor motives and teacher motives when organising field trips. The expectation of combining learning and entertainment seems to be important not only for visitors but teacher alike. He also assumes that there are more motivations which appear in different combinations when planning a field trip. These are that the topic addressed via the field trip is connected to the curriculum, different and new learning experiences are provided, life-long learning is encouraged and interest and motivation is enhanced. Tal, Bamberger, and Morag (2005) add to this list arguing that teachers organise field trips because they have the desire to change the learning environment, to provide social experiences and general enrichment as well as to provide concrete experiences with abstract and complex phenomena. However, the most often mentioned motivation for a teacher to make a particular fieldtrip is that the topics addressed during the visit are 'connected with the curriculum'.

Anderson and Zhang (2003) found that teachers take students to museums as a way to teach subject matter that cannot be covered effectively in the classroom. Therefore the field trip is considered to complement and supplement classroom teaching, although what this connection looks like in reality is not well defined. Although research has provided convincing evidence that pre- and post-processing activities performed in school enhance field trip learning outcomes and provide the link to classroom science practice, there is considerable evidence that such activities do not take place very often (Anderson et al., 2000; Cox-Petersen et al., 2003; Anderson & Zhang, 2003; Tal & Bamberger, 2008). Very little preparation is done for museum excursions, and even then, most of the preparation is technical and focuses on schedules and instructions regarding clothing and food (Griffin & Symington, 1997).

Conflicting issues arise when teachers are motivated to connect the field trip activities to their science teaching curriculum. Time constraints are often named as preventing teachers from employing pre- and post-visit strategies. In addition, teachers often do not define their goals for the field trip and they hardly ever perceive the museum activity as an engaging socio-cultural learning experience (Cox Petersen et al., 2003; Kisiel, 2003). Teachers struggle with logistical issues, various student needs and pressure for accountability that limit their ability, and willingness, to provide proper preparation and post-visit activities (Griffin, 2004). Most of the studies that have been reported about meaningful preparation or follow-up activities described research settings, in which the researchers were involved in preparing the activity with the teachers or the museum staff (Anderson et al., 2000; Bertsch et al., 2008). In addition, it would be preferable that teachers plan follow–up trips to the same museum. These further visits are considered important for understanding that an exhibit in a given context does not have to change for children to gain new and meaningful insight. Follow-up visits build on, and lead to new, learning experiences that result in new knowledge. (Wilde & Urhahne, 2008)

The LOtC educator's role

Whereas the role of the teachers in LOtC learning has already been studied extensively, little is known about the role educators play in this process.

> 'Research on the effective use of field trips and museums as school resources has been predominantly conducted from the perspective of teachers and students, despite the fact that there are museum staff, both paid and unpaid, who have responsibilities to design, organize, and implement educational experiences for visiting school groups and who have been there since the inception of museums Furthermore, such individuals have a significant role in shaping the nature of the educational experiences afforded by their museums' (Tran, 2007, p. 178).

The educators who develop and implement the visit programme are part of the memories many students retained post field trip and it is assumed that a short, educator–led lesson, as a part of the exploration through a museum gallery or other LOtC site has a positive effect on the content knowledge that students gain from their visit (Tran, 2008).

As with teachers, educators hold different perspectives and motivations when it comes to teaching and learning and these are again based on their socio-cultural setting and history. While teachers and educators share a motivation to combine learning and entertainment and to promote science learning through field trip activities, educators put considerably more emphasis on providing memorable events and offering positive experiences, irrespective of the teacher's intent or desire to primarily connect the field trip to their curriculum and curriculum standards. Educator goals are predominantly affective and developed to nurture interest in science, plants or nature as well as in engendering a desire for the student /teacher to return to their LOtC site for future educational offers. This is deemed more important than content acquisition (Tran, 2008).

Educators assume that, after many short but positive experiences, students develop an understanding of scientific phenomena. When developing a personal interest in learning about science they assume that learners will come back to LOtC institutions throughout their lifetime (Adams et al., 2008)

Expectations about what teachers and educators anticipate from each other when being merged as a team to facilitate student field trip learning experiences are rarely made explicit before or even during the visit. Tran´s (2008) qualitative study revealed roles that educators dedicate to accompanying visit teachers which are quite similar to those I have experienced myself when working with school classes at the Botanic Garden in Innsbruck. The function of the classroom teacher include being a timekeeper (e.g. arriving on time, keeping an eye on the time during the day, informing the educator early enough when the tour has to come to an end etc.), managing the students behaviour, contributing to the general progression of the lesson and being a person who offers educators a certain amount of flexibility in developing the experiences for the lesson. In many cases however, the accompanying teachers step back from their duty to facilitate student learning; they rarely interact with their students and hand over this role to the site educator in charge.

2.4.2 Learning at Botanic Gardens

Learning about plants

What is Botany?
Plant Science, synonymously called Botany or plant biology, is a discipline of biology which focusses on gaining knowledge about plants. It covers a wide range of scientific disciplines including research on structure and morphology, growth, reproduction, metabolism, development, diseases, geographical distribution, chemical properties and evolutionary relations among taxonomic groups of plants etc. Currently the system of plants includes about 400 000 plant species and it is estimated that many more have not been found or named yet. Botany includes a look back on the long history of important philosophers and natural scientist working in this field. Theophrastus 371–287 BC may have been the first we would call a botanist. As a student of Aristotle, he invented and described many principles of botany. Many important botanists- philosophers, doctors, clerics and natural scientists followed Theophrastus and their work and publications formed the foundation of our current knowledge about plants; this work continues today. Botany is an important current field within modern biological science, dealing with questions essential to human existence. In public however, botany is often seen as a rather old fashioned, phased-out model of science and its relevance for a modern society is vastly underestimated (Simpson, 2006).

Why study plants?
Plants are the basis of nearly all life on earth. They are the only organism able to transfer sun light into chemical energy (carbohydrates) which can be used by most other organisms as their only source of food energy. Therefore pants

are called primary producers and are located at the base of most food chains. In addition plants produce structural compounds such as certain amino acids and others substances essential to metabolism in many heterotroph organisms. Without plants humans, and most animals as well as a couple of microorganisms and fungi would not exist.

The appearance of photosynthesis on earth fundamentally changed our planet. The atmosphere gained oxygen. Oxygen dependent respiration occurred. This may have been a necessary precursor to the evolution of multicellular organisms such as animals and humans.

The oxygen rich atmosphere permitted the establishment of an upper ozone layer which protects life from excess UV radiation and allows organisms to inhabit more exposed niches.

The survival of plants is essential for maintaining the health of the ecosystems and they are particularly important for humans in numerous direct ways. Directly, or indirectly via the food chain, plants are our only food source. Fossil fuels, wood and charcoal are plant based energy resources. We need plants to build houses, produce paper, fibre, medicine and many more items.

Plant science is as diverse as plant use and as important. Some of the fields of plant science are very practically oriented, such as agriculture and horticulture focusing on plants as food or energy crops or on cultivating ornamental plants. Forestry is concerned with the cultivation and harvesting trees for lumber and pulp.

Pharmacognosy deals with natural drugs, many of which originate from plants. Basic research in plant science has as its goal understanding the nature of plants in great detail; how they grow and adapt to their environment, how changes in their diversity may affect the ecosystem, how they are related to each other and how they interact with their environment are only a view aspects investigated by botanists. This knowledge may or may not be of first hand practical use but has the potential to be extremely useful in the future (Simpson, 2006).

What do we know about learning about plants?

Although plant knowledge seems to be essential for understanding life on earth, plants remain a mystery to many learners, teachers and pupils alike. They do not eat, they rarely move, they do not have eyes or fur and they do not communicate with people - or at least not in any way we yet understand. Within the last few decades a phenomenon has become more and more obvious in civilized countries; although plants are the basis for all life on earth, they seem to have disappeared from textbooks as well as from young people's minds (Wandersee & Schussler, 2001).

A study investigated plant and animal photographs in elementary science textbooks and showed that animal pictures are far more numerous than those of plants. It is also three times more likely that the animal picture carries a specific name than a plant picture does. Plants are commonly identified not by their name, but by a specific plant part or life-form. (Link-Perez et al., 2010). Maple is simply called 'a tree', tulips are colourful flowers and elder is just a bush. Asked to categorize plants, pupils of all ages focus on distinguishing life-forms or use ethno-botanical criteria e.g. whether a plant is either usable/edible or non-usable/non-edible for humans. Hardly any students show knowledge about scientific strategies that enable us to put plants into families or orders (Krüger & Burmester, 2005). Although environmental sciences are still well attended courses at universities, students who choose botany as a scientific career are rare. In addition, students arrive at university with less direct experiences of plants than in former times (Uno, 2009). The Marbach-Ad (2004) study, focusing on first year college students, showed that a general interest in biology (4.7/5) and in humans (4.2/5) were key reasons why students decided to major in biology, while an interest in plants (2.1/5) was at the bottom of the list. Same results are common in studies such as PISA or ROSE.

Science education authorities are increasingly worried about the lack of interest in science in general and in chemistry and physics in particular in pupils and students. A lack of interest in mathematics and technical sciences by young people is also a matter of international concern. A large amount of funding is now provided for European educational activities that encourage student interest in these particular fields of science (Lena, 2010). Nevertheless, the obvious lack of student interest in botany is still underrepresented in public discussions.

Wandersee and Schussler (2001) coined the term 'Plant blindness' and define it *as failing to see, take notice of, or focus attention upon plants in one´s everyday life* (Wandersee & Clary 2006, p. 1.). Some authors find an explanation for this phenomenon in human psychology and argue that humans automatically 'put animals first' because they themselves belong to the Animal Kingdom (Hoekstra, 2000). In addition, human brains are designed to recognize things that are different to the surroundings, in particular when they are moving (Tunnicliffe, 1996) which may explain why humans 'see' more animals than plants. A few studies show that whenever people do notice plants and find them interesting they appreciate them in a different way to animals (Tunnicliffe & Reiss, 2000, Wandersee & Schussler, 2001). As animals may be more instantly appealing, an appreciation of plants often benefits from the guidance and shared enthusiasm of a third party (Strgar, 2007).

History of botanic gardens

There are currently 1775 botanic gardens and arboreta in 148 countries around the world. Although it is not easy to define precisely what a botanical garden is, all of them share a scientific basis.

In about 800 AD Charlemagne issued the well-known plan 'Capitulare de villis Imperialibis' which recommended that 89 specific plants should be included in estate and monastery gardens throughout his empire. Contemporary to this, Abbot Haito of Reichenau created an ideal monastery garden in St. Gall in

Switzerland which included a physic garden, a kitchen garden and an orchard and showed a layout quite often copied in historical Botanic Gardens. However, monastery gardens were only used for cultivating plants for use and not for research. The main focus of Botanic Gardens is the study of plants, which may be the reason why the history of Botanic Gardens may not be traced back as far as monastery gardens. The history of Botanic Gardens therefore is presumably rooted in the foundation of physic gardens in Italy in the 16th and 17th centuries. Gardens at that time were solely established for the academic study of medicinal plants. Medicinal gardens spread to universities and apothecaries all over Europe. The arrival of the 'age of exploration' and the beginning of international trade caused botanic gardens to experience a change in their strategic direction. More and more, the gardens promoted and encouraged botanical exploration in the tropics. Some established gardens also helped to found new gardens, which were created almost solely to receive and cultivate tropical commercial crops such as cloves, tea, coffee, breadfruit, cinchona, palm oil and cocoa. At universities, not only were tropical plant collections steadily increasing, but much more focus was put on cultivating new species from newly explored territories.

The Botanic Garden at Innsbruck University was established in 1798. After the Bavarians shut down the University of Innsbruck in 1810, the garden was reestablished in 1826. Shortly after that time, the Botanic Garden attracted more attention, not only on the national but also on the international level. The then head of the garden, A. Kerner, became world famous for his collection of Alpine plants in 1876 and was praised for his idea that each botanic garden should focus on cultivating plants from a specific area and should aim for maximum performance in that aspect. At the beginning of the 20th century, after the relocation of the Institute of Botany and the Botanic Garden from down-town Innsbruck to its current location, the aspects of research and the training of students in botany gained interest.

However, during the second half of the 20th century, their importance in the field of science research diminished, not just in Innsbruck Botanic Gardens but in many other botanic gardens as well. The garden 'role' as a hub for the collection and propagation of diverse species and as places for scientific study was relegated to a backwater. Many gardens therefore became municipal and civic 'pleasure gardens', rarely conducting scientific programmes. During this period of botanic garden history, the only real scientific activity undertaken by gardens was the accurate labeling of collections and the exchanging of seeds on a worldwide basis. Fortunately, in the last 30 years, botanic gardens have seen a revival as scientific institutions due to the emergence of the conservation movement. Conservation is now seen by many gardens as their rasion d'etre (BGCI, 2002).

Botanic garden education

When the first botanical gardens were founded in Italy in the 16th century Pisa, (founded1543/44) and Padua (founded 1545), these sites were already gardens dedicated to teaching and learning. They were used to train medical doctors and pharmacists and became centres of plant research. Later, their educational function included the training of botany students and horticulturalists, who respectively examined the plants either from the scientific point of view or with the intention of cultivation and trade in particular plants for commercial reasons. Botanical gardens founded in the 18th centuries, such as Kew Gardens (founded 1759) and many others in both Europe and the tropics, supported not only plant collections but herbaria, fruit and seed collections and extensive libraries with plant literature and paintings. An extensive network was established between gardens to share both their knowledge and living specimens. These networks are still in use today. Nowadays while the distribution of crop plants, as well as plant research has diminished, public education has become more important

Public science education at botanic gardens

Unlike zoos, botanic gardens were slow to consider education of school children as an important agenda. Only a few gardens like Brooklyn Botanic Gardens (New York), New York Botanical Garden or Kirstenbosch Botanic Garden (Cape Town) are able to look back on more than 70 years history of teacher training, children´s gardening or teacher employment. Nowadays the situation is rapidly improving. For quite a few years now, botanic gardens consider the education of school children as one of the important aspects of their remit (Sanders, 2007). A study conducted by BGCI (2007) showed that a little more than a fourth of the gardens examined (n = 120) that consider education necessary to achieve the protection of plant diversity do not have a budget dedicated to educational purposes, and there are only a few gardens that have large education departments. An average of two full time employees work in education sections in botanic gardens and for the most part only one of these has a pedagogical qualification. Only a third of the part-time educational stuff has relevant qualifications (Vergou, 2010, Kneebone & Willison, 2006). The BGCI report provides evidence that Botanic Gardens are increasingly engaging in public education, but unfortunately they failed to ask for evidence of any effects the educational provision has on learning (Vergou, 2010). Although research is increasingly clear that out-of-school learning is associated with several positive outcomes (see p. 70ff) education programmes developed and applied at botanic gardens are based mainly on practical approaches to teaching and learning. They hardly ever take education research knowledge into account. Apparently botanic gardens, as well as other Learning Outside the Classroom institutions (LOtC) do not focus on evaluation of their programs in any great detail. Action research, or science education research based on theory and evidence, is not commonly established in these settings. A survey with 475 LOtCs in the United States of America uncovered some recurring patterns around LOtCs and their support for schools and named a lack of outcome measures as one of them (Philips et al., 2007).

Although educational activities at botanic gardens are very popular with teachers and students, they are sparsely documented in science education research literature. Studies about the effectiveness of teaching and learning programmes offered by botanic gardens are rare (Sanders, 2007). As a result, botanic gardens have difficulties sharing their understanding of teaching and learning with each other and the broader educational community.

2.5 Professional Science Teaching

2.5.1 Teaching Paradigms

When we think about professional development we assume that teaching is a profession that one can be trained in and that it develops in the course of a teacher's life. This is a paradigm of teaching that might not be shared by all people and, in particular, may not be shared by botanic garden and museum educators.

Kuhn (1970) introduced the word 'paradigm' to refer to the set of practices which define a scientific discipline. Thus paradigm describes a conceptual world-view, how something is conceptualized or viewed and including a whole package of beliefs, values, attitudes and practices.

Geoffrey Squires (1999) names seven paradigms to explore the number of different views on teaching and their practical consequences.

- Teaching as a common-sense activity
- Teaching as an art
- Teaching as a craft
- Teaching as an applied science
- Teaching as a system
- Teaching as reflective practice
- Teaching as a competence

Another paradigm which has been nurtured by science centres, museums and galleries in the last few decades is:

- Teaching as an entertainment

Squires (1999) argues that the problem is to explain not how one paradigm displaces another but how a number of conflicting or competing paradigms somehow coexist. In teaching in particular, this is one reason why dual systems of teacher education have evolved in various countries. Although individual people may hold different perspectives on teaching and may put emphasis on one or the other paradigm, each of these have a substantial literature attached to it and do have their strengths and limitations. In addition individuals may not only hold one, but a set of paradigms they regard as useful to describe 'teaching' and put an emphasis on one or the other depending on the situation applied them e.g. when referring to different aspects of a teacher's life such as teacher education, teacher practice, teacher? recruitment etc.

Teaching as a common-sense activity (Squires, 1999)

Actually, there is evidence that humans do have a natural competence to teach which can be observed even with small children. Humans are able to teach others without being trained beforehand (Papousek & Papousek, 2002). So this seems to be a fundamental human skill that develops very early during childhood.

This fundamental skill may explain why teaching is so often seen as an activity that can be done by anybody without any prior training. At universities, as well as at other tertiary education sites, it is very common that people who have been trained in a science subject are expected to be efficient at teaching science. A study with 120 Botanic gardens showed that hardly any staff who worked in education held an educational degree (Vergou, 2010) Similarly, university tutors are rarely being asked to provide evidence for teaching skills when employed as professors or senior lecturers.

Squires (1999) assumes that the common sense paradigm is based on two different features

- Firstly, everybody has experience in being taught for a couple of years in life – by observing teachers during childhood and adolescence people believe they have developed an understanding of what teaching is. When it comes to teaching, many people have some idea about it already.
- Secondly, the things we do in teaching are not very different to things we do in everyday life such as organizing resources, planning events, explaining things to other people, asking and answering questions etc. So what needs to be learned is how to lecture or assess and how to manage a room full of children. It is often assumed that this can be done through a process of trial and error or by being an apprentice to a more experienced teacher.

Common-sense knowledge relies on simplified representations of the world. When teaching is regarded as a matter of common sense, it is assumed that most people can do it as most people have some common sense and experiences with teaching. Common-sense does not reflect generalisation or universality – it focuses on the situation at hand and is passed on through examples, cases and stories. It is anecdotal and therefore one cannot agree or disagree with an argument because one cannot agree or disagree with a story. Anecdotal knowledge tends to become a normative charge and an implicit expectation about concurrence and assent. This makes it more difficult for the practitioner to stand back from the practice of the group and bring his or her analytical power in. However, common sense is also associated with the notion of a cumulative experience and the idea that people acquire it over time. It is the know-how or know-why that is valued, rather than knowledge and it is assumed that experiences are instructive. A teacher cannot be awarded a higher commendation than being classified as an 'experienced' teacher (Herzog & VonFelten, 2001). Implicit thinking is often misleading because it is based on experience that draws a connection between things that is 'comfortable' not necessarily because it is right.

Teaching as an art (Squires, 1999)

Regarding teaching as an art seems old fashioned and still quite popular. Venville and Dawson published a book named "The art of teaching science: for middle and secondary school" in 2012. Although editors do not take the expression literally, the paradigm is still vivid in people's heads.

Attempts to improve the national teacher training system in Austria have called for selection criteria, or processes, to establish who should be accepted for participating in initial teacher training courses. Although this process does not explicitly argue that teachers are 'born not made'– which would imply that training does not make a difference – there is a strong sense that selection, or self-selection, may be as important as training.

The art paradigm offers an argument for those that are simply not being able to come up with solid criteria for what makes a 'good' teacher. As with the arts a judgement is assumed to be a matter of taste or perspective. The general statement is accepted that one can be a good teacher for one student and a bad one for the other.

Teaching is a matter of one's personal style and as with contemporary art – it is difficult or impossible, to tell whether something is good art = good teaching or no art = bad teaching.

Teaching as a craft (Squires, 1999)

While teaching as common-sense argues that training is not necessary and teaching as an art assumes that it is impossible to decide whether the teaching is indeed good or bad, the paradigm of teaching as a craft does call for training. One can demonstrate a craft, imitate its practice, refine it and master it. The craft paradigm sees teacher training from the 'master and apprentice' perspective. Those who see themselves as being successful in working in this craft support novice teachers by sharing their experience and thoughts, developing and providing teaching resources and lesson plans based on their own experience, as well as supporting newcomers to acquire skills they themselves have already developed. Teaching skills are acquired by observation and detailed analysis. Programmes to train people are developed and are assumed to be successful in advancing the expertise of young teachers. Logically, craft knowledge is specific to a person who has reached the master status and is often related to specific cases or situations. It may not develop into more than individual responses to local situations.

Teaching as an applied science (Squires, 1999)

In its distinct form the applied science paradigm assumes that a teacher's work involves the application of scientific principles and evidence to practical tasks. It assumes that a teacher relies on research to inform his or her practice. Research is expected to provide the knowledge needed to develop and improve teaching. It is presumed that research investigates and discovers fundamental patterns and consistencies that provide teachers with the evidence needed to intervene in events with a higher degree of confidence. The applied science paradigm requires teachers to consider research knowledge as relevant to their professional work and to engage in practitioner research themselves to inform their work.

Teaching as a system (Squires, 1999)

The paradigm teaching as a system is comparative to the terms often used to address education as whole. On a regional, national or even international level, we refer to the education system as one that sets up rules, curricula, teacher education and employment schemes, educational standards and beliefs. System theory visualizes systems as self-regulated structures composed of regularly interacting or interrelating groups of activity. The system sets standards about what teaching is and how it should look and limits the range of choices the individual teacher has. System thinking is often expressed when people complain about overcrowded curricula, limited time for teaching outdoors or the limited provision of resources.

Teaching as reflective practice (Squires, 1999)

Since the time of John Dewey, thinking about one's own practice has been termed 'reflective thinking' and has received continual attention in teacher training. The reflective practice paradigm assumes that teaching and learning about teaching are demanding tasks because they centre on complex, interrelated sets of thoughts and actions. In teaching, there is not necessarily one way of doing something, instead a range of actions can be applied to a given task. The teacher is required to search for a balance between perhaps contrary positions or to select from two or more options by considering alternatives. Teaching as reflective practice is assumed to solve classroom problems by asking teachers to disengage temporarily from the immediacy of practice and think about what they are doing and what they are thinking about it.

Teaching as a profession (Squires, 1999)

Professionalism is justified by a social framework, which is characterise by research knowledge and/or practice based standards. This quality is considered important for their representatives being or becoming experts in their field. The social group develops levels of professionalism such as e.g. the new Teachers´ Standards which came in force in the UK in 2012. These standards are assumed to set out the characteristics of excellent teachers (Coates, 2011). They set benchmarks for the basic elements of high quality teaching such as subject content knowledge, classroom performance, teaching/learning outcomes, the environment and the ethos to be created in the classroom etc. Teaching as a profession assumes that standards can be established, reached and assessed. It is expected that these standards are reliable structures that can guarantee good quality performance of those called experts in the field (in this case, master teachers).

Teaching as entertainment

Teaching as entertainment calls for learning environments that are challenging and motivating and by doing this requires learners to participate in these educational activities voluntarily. Learning is expected to be engaging, enjoyable, fun and entertaining. It stimulates all senses, is emotional and affective. Teaching as entertainment is distinguished from the type of teaching that takes place in school or at university because it provides free choice and self-directed learning spaces. Although teaching as entertainment still intends that learning should take place it is expected that it happens on the way, without any particular effort. The focus is not on a particular learning outcome or product that has been determined at the start; the emphasis is put on a joyful learning experience. TV programs, digital game-based learning, learning outside the classroom and science events such as 'researcher nights' are good examples for this paradigm.

2.5.2 Science Teaching as a Profession

Even though being a teacher at school is regarded as a 'profession' and requires a teaching degree acquired through, and certified by, the formal education system, professional standards for teachers are vague in Austria compared with those in the UK for example.

Teaching, however, does not necessarily require official training. University teachers hardly ever hold a teaching degree. The metaphors of 'Teaching as common sense' and 'Teaching as Art' seem to still be quite commonly accepted and lead to the assumption that knowledgeable people master teaching intuitively. If not, it is assumed that a sequence of trial and error steps will improve proficiency in practice. Educators in LOtC Site often follow the same tradition.

However the most important determinant for student achievement is teacher competency and this is not solely based on subject content knowledge (McKinsey and Company, 2007; Sammons et al., 2007). Science Teaching as a profession includes a spectrum of meanings, practices and ideologies which emerge out of the work and the commitments of policy makers, teachers/educators, school boards, trainers, scientists and the public and is highly related to a particular socio-cultural context. A body of research literature already provides insight and nurtures the discussion about how teacher knowledge is constructed, organised and used, or what makes a 'good teacher' (e.g. Fraser et al., 2012, Darling-Hammond et al., 2009; Darling-Hammond & Bransford, 2005, Loughran et al., 2006; Shulman, 1998a; Pollard et al., 2008; Coates et al., 2012). Different perspectives and emphasis are put on various aspects. There is no one single set of knowledge or reality associated with any model of 'the Professional Science Teacher'.

Shulman (1998a) names 'six commonplaces' shared by all professions in general which have been renamed for more clarity (*first terms* used are the original ones):

Professionals are assumed to root their work in:

- *Service to society* = 'social values': implying ethical and moral commitments
- *A body of scholarly knowledge* = 'research': forms the basis of the entitlement to practice. This knowledge is gathered in two research fields: Science education research and science research. Both research outcomes and paradigms are considered fundamental
- *Engagement in practical action* = 'practice': the need to enact knowledge in practice
- *Uncertainty* = flexibility: caused by the different needs of clients and the non-routine nature of problems, hence the need to develop judgement in applying knowledge
- *The importance of experience* = experience: the need to learn by reflecting on one's practice and its outcomes
- The development of a professional community (of teachers /science teachers) that aggregates and shares knowledge and develops professional standards.

The John Bransford and colleagues (2005) framework for understanding teaching and learning adds the teacher perspective to Shulmans 'general' aspects as a vision of professional practice that includes:

- Knowledge of learners and their development in a social context
- Knowledge of the subject /science matter and the curriculum goals
- And knowledge of teaching (Pedagogical Content Knowledge) (Shulman 1998a) in terms of subject/science matter, diverse learners assessment and classroom/group management

Schulman emphasises the enhancement of teacher and educator 'Pedagogical Content Knowledge' (PCK) as well as requiring them to refer to the body of scholarly knowledge e.g. 'science education research literature' to inform their practice.

The teacher competencies framework

Cross cultural views of teaching and learning require discussing, developing and implementing frameworks for 'teacher competencies' related to the

Knowledge and understanding	**Subject matter knowledge**
	Pedagogical Content Knowledge (PCK), implying deep knowledge about content and structure of subject matter: • knowledge of tasks, learning contexts and objectives • knowledge of students' prior knowledge and recurrent, subject-specific learning difficulties • strategic knowledge of instructional methods and curricular materials
	Pedagogical knowledge (knowledge of teaching and learning processes)
	Curricular knowledge (knowledge of subject curricula – e.g. the planned and guided learning of subject-specific contents)
	Educational sciences foundations (intercultural, historical, philosophical, psychological, sociological knowledge)
	Contextual, institutional, organizational aspects of educational policies
	Issues of inclusion and diversity
	Effective use of technologies in learning
	Developmental psychology
	Group processes and dynamics, learning theories, motivational issues
	Evaluation and assessment processes and methods
Skills	Planning, managing and coordinating teaching
	Using teaching materials and technologies
	Managing students and groups
	Monitoring, adapting and assessing teaching/learning objectives and processes
	Collecting, analysing, interpreting evidence and data (school learning outcomes, external assessments results) for professional decisions and teaching/learning improvement
	Using, developing and creating research knowledge to inform practices
	Collaborating with colleagues, parents and social services
	Negotiation skills (social and political interactions with multiple educational stakeholders, actors and contexts)
	Reflective, metacognitive, interpersonal skills for learning individually and in professional communities
	Adapting to educational contexts characterised by multi-level dynamics with cross-influences (from the macro-level of government policies to the meso-level of school contexts, and the micro-level of classroom and student dynamics)

(*Continued*)

	Subject matter knowledge
Dispositions: Beliefs, attitudes, values, commitment	Epistemological awareness (issues concerning features and historical development of subject area and its status, as related to other subject areas) Teaching skills through content Transferable skills
	Dispositions to change, flexibility, ongoing learning and professional improvement, including study and research
	Commitment to promoting the learning of all students
	Dispositions to promote students' democratic attitudes and practices, as European citizens (including appreciation of diversity and multi-culturality)
	Critical attitudes to one's own teaching (examining, discussing, questioning practices)
	Dispositions to team-working, collaboration and networking
	Sense of self-efficacy

Table 1: Aspects of teacher competence (EU Expert Group, 2013, p. 45).

particular national context in which they should be applied (EU Expert Group, 2013). Based on research, the EU Expert Group (2013) has compiled a list of competencies to be used as a reference for fruitful discussion as well as a starting point for further developments in the international arena of educational policy and practice.

Pedagogical Content Knowledge (PCK)

Pedagogical Content Knowledge (PCK) is my particular research field and is as Loughran, Berry, and Mulhall (2006) put it:

> '[. . .] to the heart of what it means to be an expert professional: one who chooses to use a particular teaching procedure, at a particular time for a particular reason, because through experience (and possibly through engagement with education research literature and professional development activities) that teacher has come to know how teaching in that way enhances student learning of the concept under consideration' (p. 9).

In contrast to practical knowledge such as classroom teaching, PCK builds on the profession's collective wisdom. Hence it is more formal and not as personal or as situated in classroom events as practical knowledge. Although directly linked to classroom practice, the concept of PCK may describe ideas or approaches that enable teachers to develop an expertise that is more adaptive to a larger range of classroom settings.

> 'PCK is a heuristic for teacher knowledge that can be helpful in understanding the complexity of what teachers know about teaching and how it changes over broad spans of time' (Schneider & Plasman, 2011 p. 533)

When Shulman published his ideas of PCK in 1987 his definition of the concept was rather vague.

> '[Pedagogical content Knowledge] represents the blending of content and pedagogy into an understanding of how particular topics, problems or issues are organized, represented and adapted to the diverse interests and abilities of learners, and presented for instruction. Pedagogical content knowledge is the category most likely to distinguish the understanding of the content specialist from that of the pedagogue '(p. 8).

The science education research community still struggles to agree on a definitive understanding of PCK. In the German speaking science education research community, Shulmans idea of PCK was taken up as 'Fachdididaktisches Wissen' which 'comprises declarative knowledge about subject specific student requirements and strategies for communication as well as procedural knowledge in terms of PCK skills (Schmelzinger et al., 2010, p. 190).

The authors cited above note that the equalisation of the Anglo-American concept of PCK (which is based on the US American curriculum traditions) with the concept of 'Fachdidaktisches Wissen' (based on German curriculum traditions) may be vulnerable.

However it seems to be legitimate to use the term PCK synonymously with 'Fachdidaktisches Wissen' because currently it is the most appropriate we have.

While Shulman explained PCK as an amalgam of content and pedagogical knowledge and exclusive to teachers' professional knowledge, research literature refers to PCK either as a discrete domain of teachers professional knowledge or as dependent on content knowledge, pedagogical knowledge and context knowledge and therefore not separable. This area of conflict nurtures multiple conceptions of PCK. The Austrian teacher education tradition refers to 'fachdidaktisches Wissen' as one of four domains in teacher education which also include, 'content knowledge', 'pedagogical knowledge' and 'practical – school based- knowledge'.

Pedagogical Science Content Knowledge (PSCK)

Pedagogical Science Content Knowledge (PSCK) intrinsically ties subject matter, including knowledge about the 'Nature of Science' and the 'Nature of Scientific Processes and Methods', to pedagogical and context knowledge. While

Components of science teacher PCK	**Categories for each component of PCK**
Orientations to teaching science	Teachers' ideas about . . . • purposes and goals for *teaching* science • the nature of *science* • the nature of teaching and learning science for *students*
Student thinking about science	Teachers' ideas about . . . • students' *initial* science ideas and experiences (including misconceptions) • *development* of science ideas (including process and sequence) • how students *express* science ideas (including demonstration of understanding, questions, and responses) • *challenging* science ideas for students • appropriate *level* of science understanding
Instructional strategies in science	Teachers' ideas about . . . • *inquiry* strategies (e.g., questions and including how to use, how science is developed, and how student thinking is supported) • science *phenomena* strategies (e.g., demonstrations or predict-observe-explain and including how to use, how science presented, how student thinking is supported) • *discourse* strategies in science (e.g., argument, writing, presenting, or conferencing and including how to use, how science portrayed, and how student thinking is supported) • general *student-centred* strategies for science (vs. teacher-centred) including how to use and when, how science is represented, and match to student needs and thinking
Science *curriculum*	Teachers' ideas about . . . • *scope* of science (importance of science topics and what science is worth knowing or teaching) • *sequence* of science (organizing science content for learning) • curricular *resources* available for science • using *standards* to guide planning and teaching science
Assessment of students' science learning	Teachers' ideas about . . . • *strategies* for assessing student thinking in science • how or when to *use* science assessments

Table 2: Science teacher pedagogical content knowledge (PCK), aspects and categories; Schneider and Plasman (2011) pp. 538–539.

considered to be domain specific, PSCK asks science teachers to have a rich conceptual understanding of their particular subject content as well as of subject related processes. They also need to have an understanding of epistemologies which need to be combined with expertise in developing, using and adapting teaching procedures, strategies and approaches to their individual learners needs in a particular learning environment (Shulman, 1989a).

In short: 'It is what teachers know about their subject matter and how to make it accessible to students (Schneider & Plasman, 2011, p. 534)

Neither the knowledge of pedagogy nor a deep knowledge of science can stand-alone. Lacking either will challenge teachers' abilities and skills as a professional. According to Schneider and Plasmans' (2011) literature review (n = 91 relevant research articles), PCK for science teaching Includes five components which are 'Orientation to Teaching Science', 'Students Thinking About Science', 'Instructional Strategies in Science`, 'Science Curriculum' and 'Assessment of Students Science Learning`. It is obvious that PCK components such as knowing about student alternative conceptions, important big ideas related to the context, conceptual hooks or triggers of learning are not well understood when rich understanding of the subject content is lacking (Loughran et al., 2006).

While PSCK is sometimes considered an academic construct the ideas are deeply rooted in the belief that teaching requires more than just delivering science knowledge to students and student learning is more than just receiving this knowledge.

In the context of this work, PCK is specifically addressed in terms of instructional strategies in science and the knowledge about this component necessary to implement inquiry based science teaching in school and at LOtC institutions.

Science educational research literature informs practice

Professionalism, in terms of wider comprehension, is also justified by professional actions, which are in line with domain specific (research) knowledge. The quality of an action is related to this domain specific knowledge. To own this professional knowledge is considered important for representatives when classified an expert in the field. In terms of professional science teaching, one has to consider that there are a minimum of four research areas that feed into this profession. These are 'science research', 'science education research', research on school related pedagogy' and 'practice based research in schools and educational settings'. The first one follows a different research paradigm than the second and the third. Practice based research may follow another set of paradigms.

Accepting all research fields as equally important for working as a professional, science teachers is particularly challenging. Whenever 'encultured' either explicitly or implicitly in science research paradigms, science teachers educational history may prevent or hinder them from accepting other epistemological approaches. In addition, the body of research knowledge is continuously developing in all fields which make it almost impossible to keep up to date even with one single research area. Research literature on science education is extensive and the outcomes of research seem to speak more to researchers themselves than to practitioners, who are on the whole not the producers of this knowledge but who are expected to be the end users. Frequently, it is also mentioned that research and practice are different in context. Research knowledge if often defined by its creation and the questions which need to be answered (Fraser et al., 2012). Thoughtful analysis of practical experience however is not meaningful until it is placed in a framework that enables professional teachers to relate it to other research findings and theorize about it. Science educational research does however have the potential to complement, contextualize and enhance the practical understanding, particularly for practicing teachers when researchers take the time to probe, analyse and evaluate practice based teaching from a variety if perspectives (Pollard et al., 2008).

2.5.3 Continuous Professional Development (CPD)

In workplace setting in general 'Professional Development' refers to:

> 'the acquisition of skills and knowledge both for personal development and for career advancement. Professional development encompasses all types of facilitated learning opportunities, ranging from college degrees to formal coursework, conferences and informal learning opportunities situated in practice.' (http://en.wikipedia.org/wiki/Professional_development)

The metaphor of 'Teaching as a Craft' presents teachers as being adaptive experts who relish challenges and are continually looking for ways to educate themselves. According to their attitude to professional development, they continuously adopt new ways of thinking. These new approaches allow a tolerance of ambiguity and for the teacher to let go of previously held assumptions as they engage in learning new skills. Others may continue to learn to become more efficient in carrying out routines they already adopt and therefore perform well in stable environments (Schneider & Plasman, 2011).

If one considers a group of professional teachers (e.g. high school biology teachers) as a social community of practice (Lave & Wenger, 1991), situational and constructive learning is assumed to take them from the margin as newly qualified teachers into the core of the community. 'Berliner (1988, 1994) describes 5 levels of skill development: novice, advanced beginner, competent, proficient and expert' (Schneider & Plasman, 2011, p. 533)

Berliner (2001) assumes that it takes at least 5 years for a newly qualified teacher to achieve expertise, irrespective of how one defines this.

The term 'Continuous Professional Development' has become a 'container concept' and again there is an absence of a shared understanding of what professional development actually is. Of course there is at least one explicit meaning connected with this term, which is: 'teachers continue to develop in their job, continuously learning from theory and practice and as a result become more experienced and efficient. Professional learning is assumed to be a continuum, starting in initial teacher training and evolving throughout the rest of a teacher's professional career.

Science education literature provides a huge variety of models for continuous professional development (CPD) for teachers. Continuous Professional Development for LOtC educators cannot draw on such a long history of research. Therefore it is assumed that whatever can be learned from research on 'formal teacher's professional development' will more or less be relevant for LOtC educators.

Professional development for teachers:
The term professional development is frequently used, but in very different contexts, referring to different practices and often with different meanings.

Klechtermans (2004) defines professional development as a learning process, resulting from the meaningful interaction between the teacher and their professional context both in space and time. This interaction eventually leads to changes in teachers' professional practice as well as in their thinking about practice.

Gusky (2000) sees professional development as a systemic process that considers change over an extended period of time and takes into account all levels of the organisation – the individual, the school, the school board, the national educational ministry etc.

He argues that CPD:

- is a learning process
- implies interaction with the context
- and leads to individual and organisational development

CPD is a term to describe all the activities in which teachers engage during their careers and which are designed to enhance their work (Day and Sachs, 2004). The main goal for CPD is that teachers' and educators' professional learning supports changes in teaching practices that result in improved student learning. The relationship between teachers professional development (PD) and teacher effectiveness, however, is not straight forward. The concept of 'Continuous Professional Development' (CPD) has been heavily criticised in terms of its ability to change teachers' practice and improve student outcomes for many years (McNicholl, 2013). CPD tends to have a small impact on teachers' learning, consequentially having little influence on their actual behaviour and even less influence on students' learning (Hattie, 2008).

A body of research knowledge about what works in CPD is already available and establishing professional learning communities (PLC) amongst participants in training courses is one of the favoured research-based recommendations (Timperley et al., 2007).

What makes Continuous Professional Development (CPD) effective?

Considerable effort has been directed to understanding the act of teaching and associated student learning outcomes. However, in terms of system engineering there seems to be another 'black box' situated between particular professional learning opportunities for teachers and their impact on teaching practice.

Based on education research outcomes, Gusky (2000) argues that 'good PD' mirrors the socio-constructivist ideas and should therefore:

- be social
- be interactive
- be context related
- challenge participants to critically review their beliefs and ideas
- be relevant to participant agendas

Groundwater-Smith and Dadds (2004) recommend focusing on five of the most important factors in CPD effectiveness:

- on learning through inquiry
- on the power of the school culture to affect teacher development positively or negatively
- on how the kinds of CPD available to teachers indirectly represent the kinds of professionals that teachers are expected to be or become
- on the importance of acknowledging values
- on evidence based practice as CPD

Wade (1984–1985) recommend four types of approaches found to be most effective on teachers' knowledge and behaviour, one of which has not been mentioned before is the

- observation on actual classroom methods and classroom practice

What is already known to be effective is unfortunately not always what is practiced. It is quite clear that listening to inspiring speakers or attending a one off workshop will rarely change a teacher's practice sufficiently to impact on student learning. However, looking at the professional development programme of the Pedagogical College in Tirol (winter term 2013/14) which is officially in charge for teachers professional development in the region, shows that most frequent offers (n = 48) addressing STEM teachers covers 4 teaching units which are about 3 hours.

Figure 5: STEM related training offers at the Pedagogical College in Tirol most often (n = 48) covers 4 teaching units (3 h), followed by those lasting for 10 units (n = 28) which is about 7.5 h. The number of PD activities covering 11–20 units (up to 14 h) add up to a total of n = 19 offers, whereas those covering 21–40h add up to a total of n = 8.

However extended programs for teacher professional development are not necessarily more effective than short term offers. There is little evidence that either the 'non-structured approach' which treats teachers as self-regulated professionals who just need time and resources to construct their own learning, or the 'tightly structured approach', where external experts develop recipes for teaching, present prescribed practices with an underpinning rational and monitor their implementation, really work. For the latter there is evidence that these processes can be affective in changing teaching practice, however either this change has limited impact on students learning outcomes or the practice is not sustained once the 'expert' tutors withdraw from the process (Hattie, 2008; Timperley et al., 2007).

Timperley, Wilson, Barrar, and Fung published an extensive study in 2007, analysing 97 core studies and a couple of supplementary studies. They summarised seven themes about what works best in professional development:

1. *Extended time for opportunities to learn was necessary but not sufficient*
   - Learning opportunities typically occurred over an extended period of time and involved frequent contact with a provider

But extended opportunities also resulted in no or low impact on students. Limited time was adequate for relatively narrow curriculum goals.

- How time was used was more important than the exact nature of provision Funding for release time and the absence of such funding were both associated with the interventions in the core studies and with that low or no impact

2. *External expertise was typically necessary but not sufficient*
   Engagement of external expertise was a feature of nearly all the interventions in the core studies with funding frequently used for this purpose

   But interventions with low or no impact also involved external experts.
3. *Teachers engagement in learning at some point was more important than initial volunteering*
   Neither who initiated the professional learning opportunities nor whether it was voluntary or compulsory was associated with particular outcomes for students.

   What was more important was that the teachers engaged in the learning process at some point.
4. *Prevailing discourses challenged*
   Where prevailing discourses were problematic, they were typically based on assumptions that some groups of students could not learn as well as others and /or emphasised limited curriculum goals.

   The challenge to discourse typically involved iterative cycles of thinking about alternatives and becoming aware of learning gains as a result of changed teaching approaches
5. Opportunities to participate in a professional community of practice were more important than place
   Interventions in the core study were both school-based an external to the school

   Nearly all included participation in some kind of community of practice but such participation on its own was not associated with change

   Effective communities provide teachers with opportunities to process new understandings and challenge problematic beliefs, which focus on analysing the impact of teaching on student learning.
6. Consistency with wider trends in policy and research
   Approaches promoted typically were consistent with current research findings, recommendations of professional bodies (e.g. national subject association) and /or current policy
7. Active school leadership
   School-based interventions in the core studies had leaders who provide one or more of the following conditions

Actively organised a supportive environment to promote professional learning opportunities and the implementation of new practice in classrooms

Focused on developing a leaning culture within the school and were learners along with the teachers

Provided alternative visions and targets for students outcomes and monitored whether these were met

Created conditions for distributing leadership by developing the leadership of others. (ibid p. XXV)

Putting all 7 recommendations into practice was essential key aim of the INQUIRE training courses, as well as for the learning environment created in the INQUIRE consortium. This will be expanded on later.

Professional Learning Communities (PLC´s)

The notion of 'Situated Learning and Communities of Practice' have been addressed elsewhere already (s.p. 23).This learning principle is currently advocated in Professional Development research and communities established within the spirit of 'situated learning' are often referred to as Professional Learning Communities (PLC). PLCs have proven to be an alternative and successful way for the long-term professional development of teachers. They provide the space for learners to discuss and exchange knowledge as well as to make use of the social capital that individual members provide (Hofman & Dijkstra, 2010).

Hord (2009) defines the term PLC by explaining each individual concept as follows:

- *Professionals* are teachers/educators who feel responsible for developing classroom practice that supports effective student learning. Professionals are highly motivated and interested not only in their students but in their own learning.
- *Learning* is what professionals do to improve their knowledge and skills.
- *Community* is a group of individuals coming together to work on meaningful tasks and to share experiences, knowledge and skills.

Hord's (1997a) extensive literature review focused on school improvement efforts.

She summarized the professional learning community as having:

- supportive and shared leadership,
- shared values and vision,
- collective learning and application,

- shared personal practice, and
- supportive conditions – relationships and structures.

Bolam, McMahon, Stoll, Thomas, and Wallace (2005) reviewed the professional development literature published since 1990 and conducted a survey with 2,300 different schools (from nursery to secondary schools). The review and the survey confirmed the existence and importance of eight key characteristics shared by successful PLC.

Successful Professional Learning Communities share:

- Values and visions
- Collective responsibilities for student learning
- Reflective professional inquiry
- Collaboration focused on learning (the group as well as the individual)
- Professional learning
- Inclusive membership
- Mutual trust, respect, support and openness
- Networks and partnership

Authors point out that: 'the case study findings supported the conclusion that the more fully a PLC expressed the characteristics, the more they impacted positively on pupils' attendance, interest in learning and actual learning as well as on the individual and collective professional learning, practice and moral of teaching and support staff' (Bolam et al., p. iii).

Huffmann and Hipp's (2003) model of five dimensions for professional learning communities add into to the above list the perspective of 'Leadership', which includes external support provided by experts as well as shared authorities, tasks, duties and responsibilities amongst members. In addition, 'practical work' is shared which includes, for example, observing each other when putting knowledge and skills into practice.

The concept of the professional learning community was a central focus addressed in the OECD study 'Teaching Practices and Pedagogical Innovation TALIS 2008' (Vieluf et al., 2012). Hence central features of professional learning communities include 5 characteristics namely:

- co-operation among teachers (such as team teaching)
- holding a shared vision,
- having a clear focus on learning,
- practicing reflective inquiry and
- engaging in the de-privatisation of practice

Affirmative actions were taken by the INQUIRE management board to nurture the development of communities of learners, as groups of individuals or as a network of organisations. To value collaborative learning processes are a central theme in the INQUIRE project design.

Reflective Practice in Professional Development

Self-reflection and self-critique are characteristics any professional should exhibit. Because teaching requires teachers to change and adapt to new situations very quickly, they need to not only learn in practice but through practice. This means considering reflective practice as one of the major tools in increasing teaching proficiency. 'Reflective Practice' in education is a term that carries different meanings in particular contexts. For some, it means thinking about something, for other it is a well-defined and crafted practice or even a highly structured approach to develop a deeper understanding. For many student teachers it is considered an imposition that needs to be fulfilled to achieve course requirements.

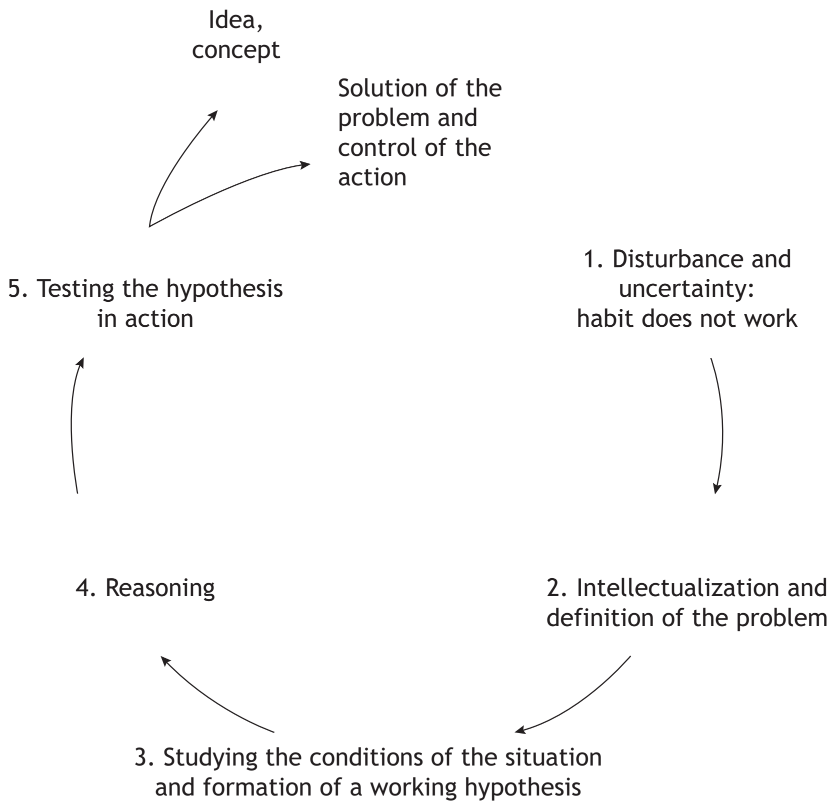

Figure 6: Dewey's model of reflective thought and action (Miettinen, 2000, p. 65).

In 1933 Dewey was already drawing the attention of teacher trainers to reflective thinking. He argued:

> 'Reflective thinking, in distinction from other operations to which we apply the name of thought, involves first a state of doubt/hesitation/perplexity/mental difficulty in which thinking originates.
>
> Secondly an act of searching/hunting/ inquiry to find material that will resolve the doubt, settle and dispose of the perplexity' (Dewey, 1993, p. 12)

According to Dewey a reflective thinking process is formed by five phases which need not necessarily occur in any particular order. The five phases are suggestions, problem, hypothesis, reasoning and testing (Loughran, 1996).

Based on Dewey notion of reflective action, Pollard and colleagues (2008, p. 14) provide seven key characteristics of reflective practice in the teaching context. These are:

1. *Reflective teaching implies an active concern with aims and consequences, as well as with means and technical efficiency*.
   Teaching practices are influenced by the wider society (education policy, parents beliefs, etc.). Hence reflective teachers should actively work on policy ideas – thus a critical attitude to policy ideas is important. A teacher is not an autonomous individual, which many teachers once thought to be and unfortunately occasionally still do. As soon as questions about education aims and social values are seriously raised a professional needs to take them into consideration and needs to develop those ideas further.
2. *Reflective teaching is applied in a cycle or spiral process, in which teachers monitor, evaluate, and revise their own practice continuously.*
   Teachers are principally expected to plan, take provisions and act. Reflective teachers monitor, observe and collect data of their own and their student's intentions as evidence to inform their own doing. This evidence needs to be critically analysed and evaluated and shared with others to finally inform further decisions. It is a continuous spiralling process towards higher-quality teaching.
3. *Reflective teaching requires competence in methods of evidence-based classroom enquiry, to support the progressive development of higher standards of teaching.*
   Methods applied are reviewing relevant existing research literature and gathering new evidence by e.g. collecting data, describing situations, processes, causes or effects. (e.g. objectively: what students actually do; or subjectively: individual perceptions). Applying analytical approaches such as interpreting data in the light of already existing research and other practitioners' knowledge and finally evaluating the scene by making judgements about the educational consequences.

4. *Reflective teaching requires attitudes of open-mindedness, responsibility and wholeheartedness.*
   All three attitudes are drawn from Dewey's 1938 notion of reflective action and are considered vital ingredients of the professional commitment that needs to be demonstrated by reflective teachers.
   - *Open-mindedness* is used as being willing to reflect and listen to more sides than one and to give attention to alternative possibilities. Thus own assumptions, prejudices and ideologies are challenged.
   - *Being responsible* means to taken moral, ethical and political issue into consideration to make professional and person judgement
   - To be *whole-hearted* asks teachers to be dedicated, single minded and enthusiastic
5. *Reflective teaching is based on teacher judgement, informed by evidence-based enquiry and insights from other research.*
   As far as teachers knowledge is solely based on individual experience and is simply believed to be valuable because it works in practical teaching there are little incentives to change even in the light of evidence supporting alternative ideas of practice. Educational research has the potential to complement, contextualise and enhance practical understanding. Thus reflective teaching is trying to merge the two knowledge areas of research based and practical based knowledge.
6. *Reflective teaching is enhanced through collaboration and dialogue with colleagues.*
   Engaging in reflective practice is most effectively done in association with colleagues because they provide the surrounding for collaborative or reflective discussions which are essential in all aspects of social learning
7. *Reflective teaching enables teachers to creatively mediate externally developed frameworks for teaching and learning.*
   Creative mediation involves the interpretation of external requirements in the light of a teachers understanding of a particular context and is often the source of essential forms of innovation for future development. (Regan & Dillon, 2013)

Reflective practice is advocated by many scholars in order to improve teacher development and is frequently recommended for teachers' professional development (Loughran, 2002).

The diversity of views on what reflective practice means how it should be done and documented and how the ability of students and teachers to become reflective practitioners can be improved, makes it difficult for both researchers and practitioners to agree on how pre- and in-service teacher programmes can support participants to develop a reflective attitude to their practice. A real and serious issue for professional development is the teacher's ability to capture, portray and share knowledge of practice in ways that are meaningful to others. Teachers engaging in reflective practice, or so called 'practitioner inquiry', however, collect evidence, which helps them share their experience and knowledge gained from practice with colleagues in a community of practice or professional learning community. Through reflective practice, professionals develop their understanding about the way they conduct their work and develop and refine their practice to become even more effective. The knowledge base generated is helping practitioners to better understand what they know and what they learn in practice and therefore supports the emancipation of practice by learning through practice (Loughran, 2002).

Loughran (2002) suggest that:

> 'effective reflective practice is drawn from the ability to frame and reframe the practice setting, to develop and respond to this framing through action so that the practitioner's wisdom-in action is enhanced and a particular outcome articulation of professional knowledge is encouraged. . . . It is through the development of knowledge and understanding of the practice setting and the ability to recognize and respond to such knowledge that the reflective practitioner becomes truly responsive to the needs, issues and concerns that are important in shaping practice' (p. 42) .

External expertise

In science teaching, external expertise can come from various fields of expertise such as 'science', 'science education research', 'learning sciences', 'psychology', 'pedagogy' etc.

Shulman (1989a) argued that scientific knowledge is inseparable from pedagogical knowledge and so expertise in subject content knowledge is extremely important. Experts in a particular scientific field are therefore often highly appreciated if they are able to provide reliable, up to date science knowledge in an 'easy to understand' way.

In addition, pedagogical, PCK or practical expertise is equality important and experts in these fields helpful to give advice.

As Timperley, Wilson, Barrar, and Fung, (2007) have found, experts are not needed per se, but they can speed up the processes of learning in CPD. It is important who these experts are and how they are able to communicate the particular knowledge they are asked to bring into a community of learners.

Practitioners themselves most often value a practical approach to learning which provides them with opportunities to observe and test their knowledge as well as skills which are required for a particular CPD training. Although the strategies of collecting and adopting 'ready to go' teaching recipes hardly ever prove to be successful for implementation in every day classroom teaching, many teachers assume that the role of the expert is to provide these 'readymade' courses of action.

2.6 Design Based Research Informs Practice

> 'The ultimate purpose of science education research is the improvement of science teaching and learning throughout the world. (Abell & Lederman 2007, p. xiii)

Educational research, however, face the challenge as Abell and Lederman identified in their introduction to the 'Handbook of Research in Science Education' published in 2007:

> 'We must take care that the proximate causes of our research (e.g. achieving publications that count for tenure, writing conference papers so our universities will fund our travel, preparing new researchers getting grant dollars) do not derail us from achieving our ultimate purpose.' (Abell & Lederman, 2007, p. iii).

Whether and how research is still suitable for informing practice is a concern increasingly voiced by scholars in the field:

> 'I believe it would not be inaccurate to say that the most powerful forces to have shaped educational scholarship over the last century have tended to push the field in unfortunate directions – away from close interaction with policy and practice towards excessive quantification and scientism.' (Condliffe Lagemann, 2001, p. 1)

Splitter and Seidl (2011) argue that:

> 'The generation of knowledge by academics often entails the neutralization of practical urgencies – such as the ability to identify problems for the sole pleasure of resolving them and not because they are posed by the necessities of life'. (p. 106)

Referring to the work of the French sociologist Pierre Bourdieu, Splitter and Seidl assume that:

> 'Social practice performed by individual actors is influenced not only by the actors '*individual disposition*' (such as origin, education and identity) but also by supra-individual '*objective structures*' (such as socially defined interests, beliefs assumptions and resources). Objective

> structures are not uniform but vary between different social spheres.' (p. 103)

Thus research and praxis are different social spheres, which exhibit different structures associated with different types of knowledge. Actors belonging to one or the other carry out their activities while facing different structural possibilities and constraints, such as being guided by different domain specific interests, beliefs and assumptions and are limited or supported by particular sets of resources. Particular conditions of one or the other field lead to a specific way of observing the world and even the language used. Splitter and Seidl (2011) cite Bourdieu to visualise a phenomenon which was frequently mentioned in this part of my work already and is most typical for science education research as it is not understood by practitioners:

> 'Instead of grasping and mobilizing the meaning of a word that is immediately compatible with the situation, we [scientists] mobilize and examine all the possible meanings of that word, outside of any reference to the situation [. . .] The scholastic view is a very peculiar point of view on the social world, on language, on any possible object of thought. (p. 105)

Science education research is often occupied by the monological paradigm of finding the universal laws or structure underpinning a phenomenon. It is predominately seeking to produce the single most coherent model of e.g. 'inquiry based science education', or 'communities of practice' and put significant efforts into examining possible meanings of terms such as 'scientific literacy' or 'pedagogical content knowledge'. By doing this, research runs the risk of overlooking the fact that knowledge is never independent of the social, historical and cultural context that gives it meaning.

An obvious theme, running through all topics addressed in the theoretical framework is the discrepancy between the researcher's perception of a concept and how this one is constantly misunderstood and modified when it is used and put into practice.

Cultural psychology design based research

> 'Design-based research is premised on the notion that we can learn important things about the nature and conditions of learning by attempting to engineer and sustain educational innovation in everyday settings. Complex educational interventions can be used to surface phenomena of interest for systematic study to better promote specific educational outcomes'. (Bell, 2004, p. 243)

'Cultural psychology design based research' recognizes the influence of the social context in which a particular work takes place. It has the potential to contribute to our understanding of learning in complex settings. In this regard, designing and developing an intervention is an explicitly theory driven activity. Theory is carefully studied and this knowledge is used to design, plan and implement a learning environment which has the potential to fulfil desired effects.

> [. . .] design based research seeks to understand the nature of the introduced changes and their consequences from the perspectives of the participant and often provides them with a voice and a source of influence on the shaping changes to their setting.' (Bell, 2004, p. 249)

Emphasis can be put on the localised nature of practices and norms of social groups investigated as they actually occur in their specific settings. It allows getting insights about the nature of organisations and suggests improvement for their educational enterprise. It helps to learn more about whether or not the design of the learning environment was appropriate for participating groups that are assumed to already have developed cultural practices before the invention begins (ibid, 2004).

Design based research is applied in this work in particular to understand more about whether a collaborative, expansive learning environment (applied design) has the potential to support partners professional development and to find out how an imposed theoretical view such as 'implementing inquiry based science education on a large scale in Europe' (Roccard, 2007) is interpreted by botanic gardens and natural history museums. Primacy is given to the interpretation of partner's activities to find out how the concept of IBST was actually understood in different venues while taking institutional norms associated with each setting into consideration

Through a retrospective analysis it is possible to map:

> '[. . .] the embodiment of particular conjectures through their design reification and to then design research studies to specifically tests the predictions that result. Such predictions pertain to both outcomes expected from the intervention and ways in which designed scaffolds are expected to function. The need to link outcomes to these expected functions across research iterations is the source of power from this analytic approach' (Sandoval & Bell, 2004, p. 200).