4. Discussion and Conclusion

4.1 Discussion

'Teaching isn't an exact science. Uncertainty is in its nature. This uncertainty calls for wise, well-founded judgment. Uncertainty is the parent of professionalism and the enemy of standardization. It is what makes teaching interesting, variable, and challenging—a job that's different every day'. (Hargreaves & Fullan, 2012 cited in Campell, 2013, p. 181)

Triggering the process of knowledge creation through collaborative learning

In 2007, the Rocard Report: 'Science Education now, a renewed pedagogy for the future of Europe' was published to support science education reform and forge a new direction by asking science and mathematics teachers, teacher trainers, Learning Outside the Classroom (LOTC) institutions and formal educational systems across Europe to implement Inquiry Based Science Education (IBSE) on a large scale. However, Inquiry Based Science Teaching (IBST) and learning is not necessarily a new, innovative approach and a remedy for all problems (see.p. 58ff). In my opinion, emphasising IBSE as 'a renewed pedagogy for the future of Europe' was a brilliant strategy because IBSE is a theoretical concept (s. p. 58ff). Therefore all those putting it into practice are required to grapple with it and construct a practical approach that covers theoretical features as well as a fit with their individual knowledge and skills and their particular socio-cultural context. Traditional models of learning often deal with tasks in which the content to be learned is well known ahead of time by those who design, manage and implement programs

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of learning. However this is not the case when implementing IBST. As a consequence, the Rocard Report (2007) asked stakeholders across Europe to engage in social learning processes while constructing and implementing a new, wider and more complex understanding of good science teaching in their individual country. The study presented here, provides evidence that collaborative, social learning processes have the potential to trigger organisational learning which finally leads to both organisational changes across the range of botanic gardens as well to the behaviour of teachers and educators.

Experience has shown that, in IBST, the collective activity systems, namely European project consortia, national educational systems, teacher training institutions, learning outside the classroom sites, science teachers etc., need to redefine themselves and their traditional models of teaching and learning science. It is not enough to simply agree on adopting IBST because as a theoretical concept it is an abstraction summarising multiple approaches to practical science teaching. Therefore, although IBSE has a long history, Capps and Crawford (2013) recently concluded that;

> 'today there is still no consensus as to what it [IBSE] actually is and what it looks like in the classroom` (p. 525)

A questionnaire applied at the beginning of the INQUIRE project revealed that many partners held a simple and experiential learning based understanding of IBST. Doing hands on activities was named as the main characteristic (Kapelari at al. 2011). Capps and Crawford's (2013) study showed that teachers in the United States, a country in which 'inquiry has been a buzz word in science education for many years' (p. 523), hold many misconceptions and myths about inquiry and equate it with questioning, student centred teaching approaches, and hands on teaching.

> 'It was particularly troubling that many teachers in this study believed they were teaching science as inquiry even when they did not (ibid, p. 522).

Capps and Crawford therefore call for the establishment of a 'unified concept of inquiry based teaching', rigorous assessment and professional development that supports teachers in learning about this particular 'unified concept of inquiry' and the nature of science (ibid).

This monological model assumes that science education is a closed system that follows a given set of rules, so that it is possible to discover direct relationships between inputs and outputs. Finding the perfect model of IBST is thought to be the key to designing successful interventions. This approach does not only ignore the fact that practitioners and students are individuals, deeply rooted in their socio-cultural context, but also that there is no such a thing as 'the one and only scientific inquiry approach'.

Science philosophers do not provide a unified concept of 'inquiry' in science research and there is no single concept of the nature of science that is fully accepted by all scientific disciplines. The nature of science is a matter of discussion (Harré, 1985, Bechtel, 1988). Agreement across all parties may never be reached and Bechtel (1988), in fact, argues that 'scientists are encouraged to engage with the issues themselves and to reach their own conclusion' (p. xii). As a result there are many variations of inquiry and any science education researcher or research group interested in analysing 'inquiry approaches' need to be aware of this.

For example Capps and Crawford (2013 p. 500) assume that 'doing inquiry' is characterised by being involved in science oriented problems, designing an investigation, prioritising evidence in respect to a problem (observe, describe, record), using evidence to develop an explanation, connecting explanations to scientific knowledge, communicating and justifying, using tools and techniques to gather, analyse and interpret data, as well as using mathematics in all aspects of inquiry. Minner, Levy, and century (2010) provide a more or less similar list of characteristics based on the NRC 2000 publication (s.p. 60ff). However neither do they focus on mathematics in all aspects of inquiry nor do they put emphasis on initial questions instead of problems. For these authors, it is 'precisely the lack of a shared understanding of the defining features of various instructional approaches that has hindered the research community making significant advancement in determining the effects of distinct pedagogical practices (Minner et al., 2010, p. 476). Capps and Crawford (2013) finally ask the question: 'If the academic community has not reached a consensus, how can we expect teachers to understand what inquiry is and how to teach science this way?' (p. 523).

After a long history of science education reform in the United States, aimed at implementing inquiry based learning, teachers and researchers still do not know what kind of knowledge, skills and attitudes are needed to design IBSE learning environments and which of those are most successful in supporting student learning (Minner et al., 2010; Capps & Crawford, 2013). Even more of a problem, the often favoured IBSE learning approach mentioned by the authors above covers neither the various approaches science takes to generate knowledge nor does it guarantee good science teaching (Dillon, 2012). Minner, Levy, and Century (2010) suggest that further work should be done to determine how practices such as 'active thinking', 'decision making' or 'drawing conclusions from data', applied outside the investigative context, contribute to student learning as compared to those taking place within the investigation context. In some instances, these have been significant predictors of increased student understanding of the science content.

Thus this raises the question of whether academics should continue to focus on 'reaching a consensus on the nature of inquiry teaching, taking care and precision in communicating what inquiry is to members of the education commu-

nity, and developing viable and usable assessments of inquiry and NOS' (ibid, p. 524) or not. This may solve the problem of the comparability of research studies which apply an experimental design but will it support practitioners to improve their practice?

We may need to reconsider whether finding the best practice model for an investigative cycle, open or structured, is really a matter of urgency and an answer to practitioner uncertainty. Models are just that- they cannot be a one size fits all answer – they always need to be adapted to the particular user's context.

Practitioners will therefore always adapt any suggested model to their own experience, knowledge, attitudes and beliefs as well as to those of their students and organisational needs and perceptions (Drake & Sherin, 2006). A study done by Miller-Day, Pettigrew, Hecht, Shin, Graham, and Krieger, J. (2013) on how a 'drug prevention curriculum' was taught` in rural schools in the US, showed that 97% of the lessons observed were adapted in some way. Reasons for adaptation included responding to time, institutional, personal, and technical constraints, as well as responding to student needs. The latter included responding to their students' ability to process the curriculum content or in order to enhance student engagement with the teaching material. Drake and Sherin (2006) reported on teacher use of a reformed mathematic curriculum and found that it showed distinctive patterns of adaptations which were related to the teacher's own experience of mathematics learning. As mentioned already, Capps and Crawford (2013) showed that teachers believed that they were teaching science as 'inquiry' even though they were not.

Even if we agree that there are different ways of doing science inquiry, this does not mean that 'anything goes' – that IBST approaches can be user-defined or that anything published under the name of 'inquiry based science teaching resources' is successful per se. Although the activities may vary, IBST is assumed to follow a 'genuine process' for gaining scientific knowledge and most of all improve student science learning outcomes. Using readymade ISBT teaching material is particularly challenging for teachers who do not have a well-grounded PSCK background (s.p. 101ff). Whenever these teachers or educators engage in adapting IBS- teaching material to their personal, student or socio-cultural needs, there is a risk that their teaching may not be as efficient as expected;

> 'Not everything in a lesson can be planned in advance. By definition, if students existing ideas are taken into account, some decisions will depend on what these ideas are. Some Ideas can be anticipated from teachers' experience and from research findings built into curriculum material, but not all. What the teacher needs is not prescribed lesson content but a set of strategies to deploy according to what is found to be appropriate on particular occasions' (Harlen, 2013).

Therefore it is inevitable that teachers and educators will need to gather evidence whether or not their science lessons are still effective. As reflective practitioners they need to formatively and summative assess whether their students will still achieve the desired learning outcomes (Harlen, 2013).

Taking this into consideration, it might be wise to come to terms with the current more or less 'precise' definition of IBST and to devote oneself to learn more about how to scaffold collaborative learning environments that engage numerous organisations and individuals in expansive knowledge creation processes as a means to increase professionalism and improve day to day science teaching inside and outside the classroom.

Scaffolding collaborative learning has the potential to improve science education

According to Lave and Wenger (1991), the motivation to learn emerges from participating in a community that values collaborative practices and aims to improve these practices to produce something useful. In the case of putting inquiry based science education into practice, contradictory views advanced by practitioners and researchers alike, as well as a very non-specific use of the term in various contexts, actually challenged the idea that a well-defined stage of proficiency and a gradual acquisition of mastery can be reached by mere participation in the community.

The INQUIRE project management team avoided putting too much effort into reaching a consensus on 'the best practice model for what IBST should look like in Botanic Gardens' and instead went for a learning outcome oriented approach (s. p. 132). Partners were expected to become aware that whenever it comes to inquiry based science teaching it is important not 'that' but 'how' one asks a question, why a particular phenomenon, an experiment or a particular hands on activity is chosen and how this is embedded in a particular learning context, how and when aspects of the nature of science are made explicit, how and whether additional information is provided, and how learners are guided through the process of active knowledge construction and transformation (s.p. 58ff). It was assumed that moving on from abstract IBS instruction to concrete practice can only be achieved through specific epistemic or expansive learning actions (Engeström, 2001). 'In expansive learning, learners learn something that is not yet there. In other words, the learners construct a new object and concept for their collective activity, and implement this new object and conception in practice' (Engeström & Sannino, 2010, p 2). In our project, botanic gardens were expected to expand their understanding of IBSE and become self-confident in running Inquiry Based Science Teacher Training Courses on site.

With two courses run and an overall project duration of 3 years, the time span might still be too short to guarantee significant organisation develop-

ment (Timperley et al., 2007). It is assumed that social communities need time to establish; not only teachers but teacher trainers and training organisations, formal and LOtC sites alike, need to engage in multiple social learning processes to develop the knowledge and skills needed to objectivise and evaluate IBSE related offers. A sustainable change in science education practices will only be achieved if enough time and space for the collaborative learning of teachers, educators and educational organisations is provided. All those involved need to adopt a critical reflective approach to teaching science and as a consequence they need to construct and develop a deep understanding of the science content as well as appropriate pedagogical knowledge in order to scaffold and assess inquiry based learning both inside and outside the classroom.

This case study, as well as outcomes published in the INQUIRE Quality Management report (Regan & Dillon, 2013) and the External Evaluation Report (Morgan, 2013), show that the INQUIRE expansive learning framework was successful in mediating the process of developing a better organisational understanding of how to apply IBSE in botanic gardens. The management board initiated their research by questioning partner understanding of inquiry and inquiry based learning, as well as the approach of traditional botanic garden teaching. By dedicating sufficient time to modelling new solutions as well as presenting and discussing practical approaches during consortium meetings, more and more partners were united in the process and 'a collaborative analysis and modelling of the zone of proximal development' (Engeström & Sannino, 2010) was initiated and carried out.

The INQUIRE grant agreement explicitly emphasised the examination and testing of new models of INQUIRE course design. Initially running a pilot INQUIRE course (PIC), reflecting on what required improvement and finally running a second INQUIRE course (IC) to establish whether the course is more successful were fundamental aspects of the INQUIRE framework and put value on Engeström's (2007) phases 4., 5.,and 6 in an expansive learning environment (see p. 35).

Traditionally, we expect learning to be manifested as change in the 'subject' which means that change becomes obvious in the behaviour and cognition of the learner. Expansive learning is manifested primarily as changes in the 'object', the outcomes of the activity system (Engeström & Sannino 2010; s.p. 31ff). The organisational learning effort developed through the implementation of the INQUIRE teacher training courses became obvious in adaptations of the initial course design and in new models of IBST activities. These observations, partner portfolios and partner interviews helped us to find out whether collective sense making and societal transformations had taken place. By studying the development of various objects, we were able to study the learning that took place across the complex and rapidly changing INQUIRE consortium activity systems.

Artefacts produced and presented in five consortium meetings, the 'train the trainer' course and the final conference offered opportunities for knowledge

exchange and feedback, as well as engagement in learning activities to develop proficiency in reflective practice. These face to face meetings set the framework for partners to engage in a sequence of questioning, criticising or rejecting IBSE practices and existing knowledge about IBSE, followed by analysis of the situation, modelling new or different perceptions of IBSE, examining a model, implementing a new version and reflecting and evaluating its success (Engeström, 2001). The Spanish team explicitly mentioned how important the consortium meetings were and how they would miss them after the project finished. For them, it was important to 'find a balance between structured and open approaches' and to overcome the common misconception that IBSE is all about 'doing hands on activities'.

The INQUIRE consortium was an organisational network which united partners with different socio-cultural and historical backgrounds. It was characterised by a horizontal movement of information between organisations as well as a vertical movement between different organisational levels (s. p. 126) such as those within the botanic garden itself, the teacher trainers and the teachers and educators participating in INQUIRE training courses. Knowledge transfer and learning was not considered to be one-way but interplay between these levels. It was expected to lead to the formation of a new level of learning located in the partnership. The Spanish portfolios of evidence and their lesson plans exhibit the clear attitudinal change that the organisation went through. Not only did the role of the student change in lesson plans from that of receiver to that of creator of knowledge. The same occurred with the teachers and educators participating in INQUIRE training courses. The Spanish team explicitly valued the contributions that teachers made to enhance their original course design and they changed certain activities accordingly. They explicitly mentioned how course participants helped them to develop their own understanding of IBSE. Course participant case study findings also informed the Spanish INQUIRE course design.

The Spanish team became increasingly aware that IBST is embedded in an investigative cycle. Later produced lesson plans predominantly emphasise IBSE investigative steps. However, none of the analysed artefacts provide insight as to the reason for that particular development. Whether this process was characterised by controversies and conflict (Engeström, 2001) or just happened as a process of mutual agreement is not evident. The Spanish team only mentioned that discussions took place and that the final version of a lesson plans is one that all members of the team finally agreed on. These later lesson plans therefore may not be interpreted as the product of individual learning and thinking. The collaborative nature of this knowledge creation process is characterised by the exchange of knowledge and shared decision making and thus it is assumed that organisational learning is reaching a deeper level.

> 'According to Stehr, objectification processes occur as social communication processes when knowledge is stored in a textual, language

> or graphic form, i.e. when it is represented symbolically. This is how society is supposed to succeed in establishing an enormous amount of objectified knowledge (. . .) that acts as a mediator between humans and nature' (Paetau, 2001, p. 3).

Mediating artefacts and objects produced during the INQUIRE project helped partners to advance their organisational knowledge in IBSE. The Spanish team explicitly valued this process and mentioned in an interview that developing written lesson plans has become an organisational strategy, which will continue even after the project has been finished. Written lesson plans provide insight into the knowledge base underpinning a particular botanic garden's education practice. Sharing those with other consortium members supported not only the Spanish team but all the consortium partners in improving their practice (Regan & Dillon 2013). In this way, the very subject of learning is transformed from belonging only to isolated individuals, teachers and educators, to the collective members in the organisation and to the INQUIRE partner network. Individual learning advances organisational learning and becomes embedded in an organisation's memory and structure (Kim, 2004).For the Spanish team, this knowledge creation process was increasingly intertwined with acquiring the skills required for putting good science teaching into practice; knowledge creation and practical skill development merged.

The INQUIRE framework asked partners to engage in inquiry to enhance their organisational development. While engaging in an 'inquiry based learning process' the Spanish team developed their INQUIRE course design and investigated whether their course participants achieved expected learning outcomes. Via this process, it was assumed that partners appreciate and value reflective practice embedded in a 'professional learning community' and understand how this can help them to improve their own skills and competences for running professional development courses at Botanic Gardens. After three years, the Spanish partner now feels confident and competent about running IBST teacher training courses successfully and argues that:

> 'Throughout the whole reflection, we are positive we can conclude that there has been a clear improvement in the practice of the courses from the first one' (PE2p11).

Critiques of expansive learning express concern about how the expansive learning cycle enables the learner to access knowledge that does not emerge directly out of practice. (Engeström & Sannino, 2010). However, the heterogeneity of the INQUIRE consortium, made up of a diverse group of competent practitioners, as well as science education researchers and scientists who were from different educational and socio-cultural backgrounds, was assumed to provide a solution to this problem. It was assumed that these personnel have the poten-

tial to provide a fruitful diversity of thought as well as access to the theoretical or research knowledge needed to expand learning (ibid). Artefact analysis provides evidence that the tension that emerged in the INQUIRE community of learners nurtured the discussion and enhanced development. Experts, practitioners, education researchers, scientists and advisory group members 'crossed boundaries' (Engeström, 2001) and gave feedback on the processes that individual organisations made to ensure that the INQUIRE courses met national needs. This heterogeneous group of experts and practitioners therefore provided the kind of 'quality assurance' needed to support partners in developing a better understanding of IBST. Evaluation reports (Regan & Dillon, 2013; Morgan, 2013), as well as this case study, reveal that many partners profited from participating in this collaborative learning environment.

The Spanish partners valued the opportunity to work not only with other botanic garden partners but with their advisory group and the academic partner, Kings College London. They explicitly mentioned the interviews conducted by Kings Colleges helped them to reflect on their work. However, artefacts from the project do not provide evidence as to whether or not the Spanish group personally examined research or theoretical literature provided by Kings College about IBSE or reflective practice or whether they just considered educational research findings as helpful or appropriate for their own practice.

Botanic Gardens and natural history museums are becoming professionals in the field of learning outside the classroom

Tran and King (2011) argue that, in terms of teaching science in a LOtC context, a distinct body of knowledge and pedagogical practice has been established amongst educators working in the field. A few of these educators are aware of the various strategies they use or their relative efficacy, however, this body of knowledge is usually neither recognized nor shared by educators working across various institutions and settings.

> 'Without a shared knowledge base underpinning practice it may be argued that the pedagogical support provided by educators in the LOtC setting is inherently compromised. Furthermore a lack of an explicitly articulated body of knowledge raises concerns as whether the field can become a profession and further develop its practice'. (Tran & King 2011, p. 282).

The purpose of the INQUIRE project was to provide a space for LOtC organisations to make this tacit knowledge explicit, to share their knowledge and to adopt a positive attitude towards reflective practice as a tool for improving educational practice. Not only the Spanish team, but all partners accepted the challenge of applying reflective practice approaches to improve their INQUIRE training course design. Many show evidence that they valued the opportunity

of sharing their knowledge with others (Regan & Dillon, 2013). A distinct body of knowledge and pedagogical practices has therefore been established, recorded and made explicit. Partners became conscious of the various strategies they use to implement IBST and learned about their efficacy; they additionally started to articulate this body of knowledge though how sustainable this movement will be is not predictable. To date, the INQUIRE consortium has provided the space for consortium partners to share and reflect on their own experience and to engage in science education theory and practice. This turned out to be fruitful for the Spanish team and they have developed a feeling of competence about applying any inquiry based science teaching approaches in the future. The staff of the Botanic Garden gained experience in the field and will try to continue running INQUIRE teacher training courses in the future:

> 'we have raised and improved our contact and understanding with teachers. It has been also positive not only to the education team but to the rest of the staff who have been involved in the development of the courses, meetings, dissemination plan, conferences, etc' (PE2/2013).

Developmental learning processes like these are more or less evident in all partner data provided for analysis (Regan & Dillon 2013).

Given the history of collaboration, it is most likely that the two Spanish gardens will continue to work together, sharing knowledge and experiences in the future. However, the fact that both Spanish INQUIRE employees, as well as several other partner INQUIRE employees, had to leave their respective organisations after the project finished may cause problems for both institutions. Kim (2004) argues that organisational learning is dependent on individuals improving their mental models. Making these mental models explicit is crucial to developing new 'shared' mental models which allow organisational learning to be independent of any specific individual. Although the Spanish team, as have other partners, produced a serious of written lesson plans which show a well-developed understanding of IBSE, more knowledge and skills are required to implement these lesson plans efficiently and effectively. The essence of the delivery is embodied more in 'the people' than in 'the written outline'. Due to work commitments in the Spanish group, these two INQUIRE employees were assigned the responsibility of designing and conducting the IBSE activities. Although sharing of ideas, knowledge and experience took place between all the Spanish partner team, there is now a high risk that this loss of 50% of the people implementing the project objectives will lead to a great loss of organisational knowledge. Any knowledge that has not been written down or articulated orally will disappear. New staff recruits to the Spanish team will have their own mental models about IBSE, and these may have no connection to the organisational memory remaining. They will have to take time to 'learn the ropes' in their

new roles and will no doubt take up a lot more time learning from those more experienced in this approach.

4.2 Conclusion

Expansive Learning Theory places the emphasis on communities as learners, on transformation and creation of culture, on horizontal movement and hybridisation and on the formation of theoretical concepts (Engeström & Sannino, 2010). This expansive cycle of learning (s.p. 35) proved to be a useful framework for structuring the learning processes in the INQUIRE network.

'There is a need for new approaches to learning, especially for understanding and supporting practices where people are creating or developing useful and reusable things in collaboration.'(Moen et al., 2012, p. ix). As knowledge and learning are highly complex concepts and are experienced in many different ways, thinking of knowledge as just being an individual constructive process is too simple and ignores knowledge that is embedded in social systems. Without challenging the traditional individualistically oriented conceptualisation of learning, one will not be able to value situated learning and knowledge creation taking place in groups, organisations and networks.

In our society, knowledge is growing exponentially and we face fundamental changes in how information is communicated and evaluated. The question is what potential this knowledge has and how it is being used in social systems such as organisations, communities, social networks and society as a whole. Vygotsky's socio-cultural theory of knowledge construction, Lave and Wenger's understanding of situated learning and Engeström's understanding of expansive learning informs the basic notion underlying the INQUIRE project path. Their understanding of how learning takes place, along with that of those that follow them, becomes visible in the basic principles informing the INQUIRE teacher training course design, the INQUIRE management structure and the decisions that were made in the course of the project implementation. The INQUIRE logic asks for a holistic approach in reviewing the process of learning on all levels - the individual, the organisation and the network as a system.

Outcomes show that the INQUIRE design was successful in supporting the Spanish botanic garden education team to develop a better understanding of inquiry based teaching as an approach :

> '. . . that it works on previous experiences, is motivating, asks for active participation of the student, includes both trial and error, promotes creativity and cooperation, is in contact with reality. Learning is meaningful and very visual' (PE2).

The organisation feels competent about implementing this pedagogy in their educational programs as well as running INQUIRE courses in the future. They

became aware about how reflective practice and formative and summative assessment can help them to improve their educational work.

4.3 Future perspectives

The Botanic Garden perspective

It would be rash to assume that botanic gardens have established a professional, theory informed, attitude towards teaching and learning within just the three years of the INQUIRE project. However, if similar collaborative learning processes continue, it is likely that partners will become professionals in botanic garden education in the near future. The first attempts have now been made and we now need to proceed to the next step. Botanic gardens need to develop a better understanding of what the 'domain specific assets of botanic garden learning' actually are. They need to actively contribute to the development of a theory of botanic garden learning. Whenever they think about the content and the context in which botanic garden learning takes place, it is recommended that they value the heterogeneity of their educational audiences, their socio-cultural background and the knowledge and experiences visitors already bring to any constructivist or situated learning activity. In addition, botanic garden educators and educational programme designers need to be aware that their own cultural background, beliefs and attitudes, not just towards their participants, but also towards teaching and learning is very influential on the learning environment they create. Focusing on the accuracy of just the science content may not be enough for modern botanic garden teaching and learning. It could also be worse if educators fail to reflect on their own science learning history or experience and simply adopt teaching approaches similar to those practiced in schools. Learning in a botanic garden may run the risk of losing the very essence that makes it unique.

The Research Perspective

Design based research has provided evidence that the collaborative INQUIRE learning environment was fruitful in improving educational practice at botanic gardens. Future investigations will focus on operational aspects of the proposed framework by analysing the social interaction amongst organisations more thoroughly. Social network analysis (Borgatti, 2013) has already been tested as a tool for visualising interactions amongst teachers and educators participating in the Austrian INQUIRE courses (see conference Publications) and the preliminary results are promising. This could be a way of assessing developmental processes taking place during the life span of a collaborative network and thus offer opportunities to scaffold this process more effectively.