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A. Background to this report

This report is a deliverable of Work Package 5 (WP5) of the European FP7-funded project "European Science and Technology in Action: Building Links with Industry, Schools and Home" (ESTABLISH; 244749, 2010-2013). It meets the requirements of the Deliverable 5.1 by presenting a report on effective instruments and tools for evaluation of IBSE with in-service and pre-service teachers as developed by the beneficiaries of ESTABLISH. (See Table 1 below for beneficiary list).

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B. The ESTABLISH consortium

Beneficiary short name	Beneficiary name	Country	Abbreviation
DCU	DUBLIN CITY UNIVERSITY	Ireland	IE
AGES	AG EDUCATION SERVICES	Ireland	IE
UCY	UNIVERSITY OF CYPRUS	Cyprus	CY
UmU	UMEA UNIVERSITET	Sweden	SE
JU	UNIWERSYTET JAGIELLONSKI	Poland	PL
CUNI	UNIVERZITA KARLOVA V PRAZE	Czech Republic	CZ
AL	ACROSSLIMITS LIMITED	Malta	MT
UPJS	UNIVERZITA PAVLA JOZEFA ŠAFÁRIKA V KOŠICIACH	Slovakia	SK
COUO	CARL VON OSSIETZKY UNIVERSITAET OLDENBURG	Germany	DE
UTARTU	TARTU ULIKOOL	Estonia	EE
UNIPA	UNIVERSITA DEGLI STUDI DI PALERMO	Italy	IT
MaH	MALMÖ UNIVERSITY	Sweden	SE
IPN	LEIBNIZ-INSTITUT FUER DIE PAEDAGOGIK DER NATURWISSENSCHAFTEN UND MATHEMATIK AN DER UNIVERSITAT KIEL	Germany	DE
CMA	CENTRE FOR MICROCOMPUTER APPLICATIONS	Netherlands	NL
MLU	MARTIN LUTHER UNIVERSITAET HALLE-WITTENBERG	Germany	DE

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Introduction

This report will inform the development of appropriate teacher profile instruments to determine teachers' attitudes, beliefs and knowledge of learning processes associated with inquiry based teaching. Section 1 reports on the key characteristics / attributes of science teachers in an inquiry classroom and Section 2 reviews the instruments that have been developed to evaluate and assess these attributes / characteristics. Many of these instruments rely on observation and teacher interviews rather than paper and pencil instruments and tools. In Section 3 discusses the differences reported in the characteristics between pre-service teachers and in-service teachers in relation to inquiry teaching and learning.

1. Characteristics of Inquiry Teachers

This section examines the attributes of an inquiry teacher and the tools and instruments that have been used to determine changes in these characteristics in teachers.

Inquiry based teaching changes the traditional role of the instructor to that of a facilitator of learning. National Science Education Standards (NSES) advocate that teachers "create an environment in which they and students work together as active learners" and orchestrate learning so that students are engaged, focussed and challenged throughout each class (National Research Council, 1996). Posing questions and problems that are relevant to students' lives are core to the process. According to Driver et al. (1994 cited in Crawford, 2000) inquiry teachers assist the improvement of students' current knowledge by encouraging students' involvement in hands on activities relevant to real world phenomena and "engaging in higher level thinking and problem solving". In turn, there is a shift from teacher centred to more student centred classrooms.

Table 1 summarises key characteristics / attributes of the science teacher in an inquiry classroom, as stated by NSES (National Research Council, 1996) as well as the types of activities that occur there.

- *Teachers must have theoretical and practical knowledge and abilities about science, learning, and science teaching (p.28).*
- *Teachers who are enthusiastic interested, and who speak of the power and beauty of scientific understanding instils in their students some of those same attitudes (p.37).*
- *Teachers must encourage and model the skills of scientific inquiry, as well as the curiosity, openness to new ideas and data, and scepticism that characterize science.*
- *Effective teachers design many of the activities for learning science to require group work, not simply as an exercise, but as essential to the inquiry.*
- *Teachers focus inquiry predominantly on real phenomena, in classrooms, outdoors, or in laboratory settings, where students are given investigations or guided toward fashioning investigations that are demanding but within their capabilities (p.31).*
- *Teachers work together as colleagues within and across disciplines and grade levels (p.30).*
- *Inquiry into authentic questions generated from student experiences is the central strategy for teaching science (p.31).*
- *In the science classroom envisioned by the Standards, effective teachers continually create opportunities that challenge students and promote inquiry by asking questions (p.33).*
- *At all stages of inquiry, teachers guide, focus, challenge, and encourage student learning (p.33).*
- *In successful science classrooms, teachers and students collaborate in the pursuit of ideas, and students quite often initiate new activities related to an inquiry.*

Table 1. National Science Education Standards view on inquiry based science teaching (National Research Council, 1996)

Making the transfer from traditional teaching roles to constructivist teaching roles has been a tedious and difficult process. The attributes of an inquiry oriented teacher described by the NSES are not easily attained, and long term ongoing support for teachers is necessary so that "teaching changes gradually, continually and for the long term" (Zion et al., 2007).

Three key factors that influence the use of inquiry in the classroom by a teacher: personal beliefs, confidence in scientific knowledge and confidence in dealing with uncertainty are briefly discussed in the following sections.

1.1 Personal Beliefs

The struggle that both in-service and pre-service teachers have in adopting inquiry practices can stem from deep-set personal beliefs and histories with their own education. Eick and Reed (2002) demonstrated how teacher role identities are influenced strongly by the individual's own lived experience of teachers as well as the strength of their teaching beliefs. The result of teacher interviews in this study showed that teacher education is not enough to instil inquiry methodologies in a teacher but the mode of instruction that he/she was exposed to as a student themselves greatly influenced the type of teacher they would become. An individual is shaped by the experiences they encounter through life, and in that sense, previous experiences with education and positive or negative teacher role models can shape the individual as a teacher themselves. Having strong beliefs about teaching, based on reflection of these past experiences, can also lead to a stronger role as a teacher in the classroom. "A strong teacher role identity, in practical terms, means that the individual has a much larger repertoire of appropriate and well thought out teacher actions on which to fall back; an accumulation of countless hours observing positive role models and reflection upon strategies that best suit their personality and perceived needs" (Knowles 1992, cited in Eick and Reed, 2002).

1.2 Confidence in scientific knowledge

Inquiry teachers must be confident in their scientific knowledge, or at the very least must be confident and comfortable with delving into areas with students that are unknown to themselves. Some teachers involved in the Biomind Programme in Israel (Zion et al., 2007) commented in their profiling interviews that they are uncomfortable with not knowing all the answers that inquiry investigations can bring about and tend to steer students toward questions to which the teachers knows the answers to or investigations that they can expect the outcome of. Some teachers deliberately made use of "safe questions" so that the students maintained faith in their knowledge as a teacher and so that the students themselves felt progress in knowing the answer. Zion et al. (2007) commented that many of the teachers received little or no scientific research experience in their own education which may contribute to the lack of their scientific content knowledge.

1.3 Confidence in dealing with uncertainty

Inquiry teachers must overcome any insecurities about feeling inadequate as a teacher when they do not know the answer. Some teachers involved in the Biomind programme (Zion et al., 2007) considered uncertainty to be fundamental to good inquiry and revelled in the chance to learn more:

"*Uncertainty is both difficult and enjoyable at the same time. I did not always know where to go…It was very interesting for me to investigate and learn new things. Sometimes the students shared knowledge that was new to me. It is a pleasure to discover new things, as a teacher*" (Zion et al., 2007).

Unexpected results from experiments or research literature can lead to changes to the overall topic investigation. Teachers must be able to cope with such changes and continually encourage students as they delve deeper into solving the problem. This can be seen as a problem aspect to some teachers (Zion et al., 2007) as they find the topic harder to handle when this occurs. Mistakes and unexpected results are part of the inquiry process and allow students to examine new paths to overcome these obstacles leading to a deeper understanding of the topic in question. Teachers must encourage students to develop and refine investigative questions, plan valid investigations that keep variables in mind, and to interpret evidence (Lehman et al, 2006). A Biomind teacher stated:

"*These are the points that are important to me; encountering mistakes, designing and realising that experiment doesn't work and why. Mistakes should be part of the experiences of what-is-inquiry*".

Crawford (2000) studied one exemplary inquiry teacher over a year to understand exactly how he implemented such a successful inquiry classroom. "Jake", a second level biology teacher, engaged his students in several ecological research projects throughout the year and numerous instructional features distinguished him from more traditional didactic teachers. Firstly, Jake related all of the projects to real world dilemmas and phenomena. When planning these projects, Jake felt it was important to consider how the research would engage and have an impact on the students while also being constructive to their scientific knowledge. During the projects he would regularly emphasise to the students the importance of their research and his own interest in the results. The difficulty for many teachers is that they themselves have been educated under concept-based programmes and this background may inhibit or slow down their shift to a more context-based method of instruction (King et al., 2008). Context-based approaches allow students to see the relationships between important concepts in their curriculum provided that the teacher links these concepts to the students' lab work and that the links themselves are made unambiguous (King et al., 2008). Jake successfully made these connections and moreover was unconcerned with not knowing all the answers to student questions. He displayed an eagerness to understand the unknown and in the process created an exciting environment for students to learn and research authentic information.

"*I don't really know what we're going to find out. It is really going to be interesting to get some data and to get some base line data for comparison, might give some ideas for questions we might want to ask further, might give us some indications as to what kind of condition the river is in… I really have no idea*" (Transcribed from an ecology lesson (Crawford, 2000)).

This attitude encouraged a classroom dynamic whereby both the students and teacher were equal members of a team intent on investigating a particular topic.

Obstacles that teachers report as barriers or deterrents to engaging with inquiry in the classroom will be discussed in a further report of the ESTABLISH project (Deliverable 4.1).

2. Instruments for evaluating teachers

The use of inquiry in the classroom by a teacher has been reported to be influenced by:

- Teachers' attitudes and personal beliefs (Lotter, Harwood, & Bonner, 2007).
- Their views on the nature of science (Schwartz, Lederman, & Crawford, 2004; Lederman, 1992).
- Their understanding of inquiry (Crawford, 2000; Damnjanovic, 1999).
- Their previous experience (Eick & Reed, 2002).

This section reviews the instruments that have been used to determine these factors and the key instruments reviewed are presented in Table 2. Each instrument is discussed separately in the following sections.

2.1 Teaching and Learning International Survey (TALIS)

The Organisation for Economic Co-operation and Development (OECD) developed the Teaching and Learning International Survey (TALIS) as part of its Indicators of Education Systems (INES) Project. TALIS is used to compare aspects of working conditions and teaching practices in schools across Europe. The report from the TALIS is available on the OECD website. (Organisation for Economic Co-operation and Development, 2010). Two sections of the TALIS survey are relevant to inquiry, namely "Teachers' Beliefs about Teaching" and "Teachers' Teaching Practices" (see Appendix A.1). Within "Teachers' Beliefs about Teaching" participants were asked to indicate their level of agreement to a number of statements. Each question correlated to a particular mode of teaching; either direct transmission beliefs or constructivist beliefs. According to the TALIS report on the first set of results (2009),

"constructivist beliefs are characterised by a view of the teacher as the facilitator of learning with more autonomy given to students whereas a direct transmission view sees the teacher as the instructor, providing information and demonstrating solutions."

From the answers given by participants, a profile can be constructed of each teacher on direct transmission versus constructivist beliefs. Examples of statements are given in Table 3.

Teacher Profiling Instruments				
Name	***Instrument***	***Description***	***Type***	***Reference***
TALIS	Teaching and Learning International Survey	Contains relevant sections under the headings "Teacher's Beliefs about Teaching" and "Teachers Teaching Practices". These address direct transmission and constructivist beliefs as well as their stance on structuring practices, student oriented practices and enhanced activities used in the classroom.	Questionnaire	Organisation for Economic Co-operation and Development. (kein Datum). *OECD Teaching and Learning International Survey (TALIS) Home*. http://www.oecd.org/document/0/0,3746,en_2649_33723_38052160_1_1_1_1,00.html Organisation for Economic Co-operation and Development. (2010). *TALIS 2008 Technical Report.* Paris: OECD Publications.
RTOP	Reformed Teaching Observational Protocol	Assesses the level teaching has been reformed in science and mathematics from the perspective of an observer of the classroom in question rather than the teacher. It consists of 25 items divided into three groups, the second and third of which contain subsets:Lesson Design and Implementation; Content - Propositional Pedagogic Knowledge & Procedural Pedagogic Knowledge; Classroom Culture - Communicative Interactions & Student/teacher Relationships.	Observational instrument	Piburn, M. S. (16. August 2007). *Reformed Teaching Observational Protocol*. http://physicsed.buffalostate.edu/AZTEC/RTOP/RTOP_full/index.htm Piburn, M., & Sawada, D. (2000). *Reformed Teaching Observational Protocol (RTOP): Reference Manual* . Tempe, AZ: ACEPT Technical Report No. INOO-3.
ESTEEM	Expert Science Teaching Educational Evaluation Model	A set of 5 instruments designed to build teacher profiles from multiple perspectives after a period of professional development. The instruments include; The Classroom Observation Rubric , Student Outcome Assessment Rubric , Teaching Practices Inventory, Science Grading Practices, and the Concept Mapping Rubric.	Questionnaires and Observational instrument.	Burry-Stock, J. A., & Oxford, R. L. (1993). *Expert Science Teaching Educational Evaluation Model (ESTEEM) for Measuring Excellence in Science Teaching For Professional Development.* Washington, DC: Office of Educational Research and Development (ED).
PSI	The Principles of Scientific Inquiry-Teacher/ -Student	Used to assess the level at which students are engaged in inquiry from a student and teacher perspective. They can be used with RTOP. 5-point Likert scale on frequency of inquiry classrooms used. There are 20 items in all with 4 items in each of the five topics; Framing research questions, Designing investigations, Conducting investigations ,Collecting data, Drawing conclusions. The items in the instrument are not only classified under these headings but are also categorised as either Factor 1 or Factor 2. Factor one constitutes the shift from teacher centred to more student centred practices whereas Factor 2 corresponds to the use of traditional methods of teaching .	Questionnaire	Campbell, T., Abd-Hamid, N. H., & Chapman, H. (2010). Development of Instruments to Assess Teacher and Student Perceptions of Inquiry Experiences in Science Classrooms. *Journal of Science Education* , 21:13-30.
		Assesses beliefs of both student and teacher toward the frequency		Taylor, P, Fraser, B., & Fisher, D. (1997).

CLES	Constructivist Learning Environment Survey	of constructivist practices utilized in the classroom on 5 point likert scale. One student CLES form (CLES-S) and two CLES teacher forms (CLES-T), one for Mathematics and the other for Science. There are 42 statements in all, which are either positive or negative in regards to inquiry practice. There are five different scales to which the statements fall under: The Personal Relevance Scale, the Scientific Uncertainty Scale and the Critical Voice Scale. Shared Control Scale, Student Negotiation Scale, and the Attitudes Scale.	Questionnaire	Monitoring constructivist classroom learning environments. *International Journal of Educational Research*, *27 (4)*, 293-302. Taylor, P. C. & Fraser, B. J. (1991). Development of an instrument for assessing constructivist learning environ- ments. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA
TPPI	Teachers' Pedagogical Philosophy Interview	Used to understand teacher attitudes, values, beliefs towards their teaching. There are two types of TPPI for beginning teachers; first year teachers and second/third year teachers second and third year. Answers can show either a teacher centred or student centred approach to teaching.	Interview	Richardson, L. & Simmons, P. (1994). Self-Q research method and analysis, teacher pedagogical philosophy interview, theoretical background, samples of data. Research technical report. Athens, Georgia: The University of Georgia.
STIR	Science Teacher Inquiry Rubric	Observational tool used to assess teachers' level of inquiry based practices in the classroom from teacher centred to learner centred.	Observational Instrument	Beerer, K., & Bodzin, A. (2004). How to develop inquiring minds. District implements inquiry-based science instruction. *Journal of Staff Development* , Vol. 25, No. 4, 43-47. Beerer, K., & Bodzin, A. M. (2003). Promoting Inquiry Based Science Instruction: The Validation of the Science Teacher Inquiry Rubric (STIR). *Journal of Elementary Science Education* , Vo. 15, No. 2, 39-49.
VNOS	Views of Nature of Science	Open ended instrument used to test the level of incite both students and teachers alike share about scientific knowledge and its development. The questionnaire, alongside individual interviews, cover the areas of "The Empirical Nature of Scientific Knowledge", "Observation, Inference and Theoretical Entities in Science", "Scientific Theories and Laws", "The Creative and Imaginative Nature of Scientific Knowledge", "The Subjective and Theory-laden Nature of Scientific Knowledge", "The Social and Cultural Embeddedness of Scientific Knowledge", "The Myth of the "Scientific Method"" and finally "The The Tentative Nature of Scientific Knowledge" There are 3 forms of the VNOS instrument; Form A (second level students), B (pre-service teachers) and C(undergraduates, graduates and pre-service teachers).	Questionnaire and individual interviews.	Abd-El-Khalick, F., Lederman, N. G., Bell, R. L., & Schwartz, R. S. (2001). Views of Nature of Science Questionnaire (VNOS). Toward valid and meaningful assessment of learners conceptions of the Nature of Science. *Proceedings of the Annual Meeting of the Association for the Education of Teacher in Science*. Costa Mesa, CA.
		Assesses pre service teachers self efficacy in teaching inquiry based science. It consists of 69 items and participants are required to		Smolleck, L. D., Zembal-Saul, C., & Yoder, E. P. (2006). The Development of an Instrument to

TSI	Teaching Science as Inquiry	respond how much they agree with each statement. The statements address the five pillars of inquiry that are set forth by the National Science Education Standards: 1. Learner engages in scientifically oriented questions 2. Learner gives priority to evidence in responding to questions 3. Learner formulates explanations from evidence 4. Learner connects explanations to scientific knowledge 5. Learner communicates and justifies explanations	Questionnaire	Measure Preservice Teachers' Self-Efficacy in Regard to The Teaching of Science as Inquiry. *Journal of Science Teacher Education* , 17:137-163.
SAS	Science Attitude Survey	Preservice vs. Inservice Instrument using 5 point Likert scale measuring level of agreement (from “strongly disagree “to “strongly agree”) both groups have toward statements assessing inquiry based beliefs and practices	Questionnaire	Damnjanovic, A. (1999). Attitudes Toward Inquiry-Based Teaching: Differences Between Preservice and In-service Teachers. *School Science and Mathematics* , PP:71-78.

TABLE 2 – Summary of main tools and instruments used to profile teachers.

Direct Transmission Beliefs	*Constructivist Beliefs*
Effective/good teachers demonstrate the correct way to solve a problem.	My role as a teacher is to facilitate students' own inquiry.
Instruction should be built around problems with clear, correct answers, and around ideas that most students can grasp quickly.	Students learn best by finding solutions to problems on their own.
How much students learn depends on how much background knowledge they have – that is why teaching facts is so necessary.	Students should be allowed to think of solutions to practical problems themselves before the teacher shows them how they are solved.
A quiet classroom is generally needed for effective learning.	Thinking and reasoning processes are more important than specific curriculum content.

Table 3. Direct Transmission and Constructivist statements taken from TALIS (2009).

In the section of TALIS entitled, "Teachers' Teaching Practices", participants indicate their frequency of use of certain practices in the classroom, from "Never/Hardly ever" to "In almost every lesson". Each statement is related to a particular index about different applications of teaching. These include Structuring Practices, Student Oriented Practices and Enhanced Activities as shown in Table 4.

Structuring Practices	*Student Oriented Practices*	*Enhanced Activities*
I explicitly state learning goals.	Students work in small groups to come up with a joint solution to a problem or task.	Students work on projects that require at least one week to complete
I review with the students the homework they have prepared.	I give different work to the students that have difficulties learning and/or to those who can advance faster.	Students make a product that will be used by someone else.
At the beginning of the lesson I present a short summary of the previous lesson	I ask my students to suggest or to help plan classroom activities or topics.	I ask my students to write an essay in which they are expected to explain their thinking or reasoning at some length.
I check, by asking questions, whether or not the subject matter has been understood.	Students work in groups based upon their abilities.	Students hold a debate and argue for a particular point of view which may not be their own.

Table 4. Structuring Practices, Student Oriented Practices and Enhanced Activities statements taken from TALIS (2009).

2.2 Reformed Teaching Observational Protocol (RTOP)

Assessment of classroom practice by an observer, using an instrument called the Reformed Teaching Observational Protocol (RTOP) was developed by Piburn and Sawada (2000) for the Arizona Collaborative for Excellence in the Preparation of Teachers (ACEPT) to assess the level teaching has been reformed in science and mathematics. Now a widely circulated instrument (Piburn M. S., 2007, Campbell *et al*., 2010), an observer marks (on a 5 point scale) the extent of inclusion of a particular activity within the classroom (see Appendix A.2). It consists of 25 items divided into three groups, the second and third of which contain subsets:

1. Lesson Design and Implementation
2. Content: Propositional Pedagogic Knowledge
   Content: Procedural Pedagogic Knowledge
3. Classroom Culture: Communicative Interactions
   Classroom Culture: Student/teacher Relationships (Piburn M. S., 2007)

The first category "Lesson Design and Implementation", addresses what ACEPT considers to be a reformed classroom. This involves the assessment of students' prior knowledge, efforts to engage students and work collaboratively in the classroom, allowing students to alter the direction of the lesson based on their investigations as well as appreciating a number of solutions to problems (Piburn & Sawada, 2000). The second category 'Content' is divided into two subsets assessing the content of the lesson and then the level of inquiry involved based on the ACEPT view of inquiry. The final category 'Classroom Culture', is designed to gauge the classroom environment and the relationships between individuals.

Instruction manuals for RTOP are available which also contain the training guides for observers. These include videos of particular situations that the observer can use to become familiar with the observation grid.

RTOP has been used to track teacher change in studies by Kimble, Yager and Yager (2006) as well as Akcay (2007).

2.3 Expert Science Teaching Evaluation Model (ESTEEM)

In order to measure expert science teaching in constructivist student centred practices, the Centre for Research on Educational Accountability and Teacher Evaluation (CREATE) designed a set of five instruments under the name of Expert Science Teaching Evaluation Model (ESTEEM) (Burry-Stock & Oxford, 1993). These instruments are designed to build teacher profiles from multiple perspectives after a period of professional development. The five instruments in ESTEEM are: (see Appendix A.3):

- The Classroom Observation Rubric,
- Student Outcome Assessment Rubric,
- The Teaching Practices Inventory,
- Science Grading Practices Inventory,
- Concept Mapping Rubric.

The first instrument, The Classroom Observation Rubric, is used by an observer in a classroom to assess the level of constructivism that underlies the teacher's instruction. Items in this rubric are categorised under four headings:

1. Facilitating the Learning Process
2. Content-Specific Pedagogy
3. Contextual Knowledge
4. Content Knowledge.

In the Content Specific Pedagogy section, a teacher is rated on a scale from 1 to 5, with 5 meaning the "Teacher is constantly making the content of the lesson relevant to student understanding" and 1 representing the "Teacher does not make the content of the lesson relevant to student understanding".

The Student Outcome Assessment Rubric works in concert with the Classroom Observation Rubric to give the observer an idea of both the teachers' practice and also the effect it has on the students' learning. An observer assesses student responses to two open ended questions and rates them from 1 to 5 based on the information in the rubric. For example, asking a question to determine if students understood the main idea of a particular topic, the rubric rates 1 as the student having little or no understanding of it, whereas 5 would involve students that state the main idea of the topic and go into detail describing it in their own words.

The Teaching Practices Inventory, the third ESTEEM instrument, also works alongside the Classroom Observation Rubric by determining the teachers' responses to their practice in the observed classroom. There are 30 items in this questionnaire where teachers are required to answer how often they believe they use different practices such as "Your students are responsible for their learning", "Your students are actively engaged in asking questions throughout the lesson", and "Your students are actively engaged in implementing activities throughout the lesson". The Science Grading Practices Inventory asks teachers to rate how competent they feel in assessing students in the science classroom across 66 items, such as in "Using science notebooks", "Using laboratory manuals", "using hands-on activities", "Using group class presentations", and "Using informal teacher observations" to name but a few.

The final instrument, called the Concept Mapping Rubric, consists of 5 different categories:

1. Concepts
2. Simple Concept Relations
3. Conceptual Relations
4. Cross links
5. Conceptual Understanding

Under these categories, students and teachers are rated on their understanding of concept maps.

ESTEEM aims to provide a rich source of information of teacher and student behaviours with regard to different aspects of expert constructivist practices. Also, the variety of perspectives studied allows the build up of a complete picture of the pedagogy adopted in a particular classroom.

2.4 Principles of Scientific Inquiry–Teacher & Student (PSI-T & PSI-S)

Using instruments which target not only teachers' beliefs but also students' beliefs about inquiry based science teaching can highlight differences between student and teacher opinions on the level of inquiry being conducted in the classroom. These differences can be used as a reflective tool by teachers to alter any areas of their inquiry instruction that need attention. The Principles of Scientific Inquiry – Teacher (PSI-T) and the Principals of Inquiry – Student (PSI-S) (Appendix A.4) are a set of instruments which are used to assess the level at which students are engaged in inquiry (Campbell, Abd-Hamid, & Chapman, 2010). In addition they can be used in conjunction with RTOP, to detect any differences between student/teacher reports with those of a classroom observer (Campbell, Abd-Hamid, & Chapman, 2010). Participants are asked to report the frequency of use of inquiry practices in the classroom. There are 20 items in all with 4 items in each of the five topics:

1. Framing research questions
2. Designing investigations
3. Conducting investigations
4. Collecting data
5. Drawing conclusions

The items in the instrument are not only classified under these headings but are also categorised as either Factor 1 or Factor 2 where Factor 1 constitutes the shift from teacher centred to more student centred practices whereas Factor 2 corresponds to the use of traditional methods of teaching (Campbell, Abd-Hamid, & Chapman, 2010). Eighteen of the twenty items correspond to inquiry oriented practices whereas the remaining two refer to methods opposed to inquiry. This instrument is particularly useful in indicating the degree to which students have become engaged in inquiry, both from the student and teacher points of view (Campbell, Abd-Hamid, & Chapman, 2010).

2.5 Constructivist Learning Environment Survey (CLES)

Similarly, the Constructivist Learning Environment Survey (CLES), developed by Taylor and Fraser (1991) uses both student and teacher perspectives to determine the extent of constructivist practices utilized in the classroom. It was later refined by Taylor, Fraser and Fisher (1997) and used widely in other studies such as Akcay (2007) which focussed on the change in a teacher with very traditional views of instruction. There is one student CLES survey (CLES-S) and two CLES teacher surveys (CLES-T), one for Mathematics and the other for Science. In the science CLES-T, there are 42 statements in all, (see Appendix A.5) which are either positive or negative with regards to inquiry practice. The participants are required to choose on a 5 point Likert scale, how often the practices associated with the statements are used in their class. There are six different scales to which the statements fall under, namely:

- The Personal Relevance Scale,
- The Scientific Uncertainty Scale,
- Critical Voice Scale,
- Shared Control Scale,
- Student Negotiation Scale,
- Attitudes Scale.

The Personal Relevance Scale contains statements which assess the extent to which the teachers believe the work their students are doing is relevant to their lives outside of the classroom. Ideally their teaching should allow students to become engaged with science which is relevant to things they witness and are interested in within their everyday lives as well as allow them to develop their existing scientific knowledge (Office of Educational Research and Improvement (ED), 1997).

The Scientific Uncertainty Scale involves statements which aim to address teachers' opinions on how their students feel about the tentative nature of science. Theories and laws are ever changing and science itself is worked around human cultural issues and interests. Students should not perceive scientific knowledge as definite and fixed information nor should they believe it to be void of human interest and unshaped by cultural issues (Office of Educational Research and Improvement (ED), 1997).

The Critical Voice Scale tries to assess the level at which teachers believe their students feel confident and competent to address issues about their learning. "The teacher should be willing to demonstrate his/her accountability to the class by fostering students' critical attitudes towards the teaching and learning activities"(Office of Educational Research and Improvement (ED), 1997).

The Shared Control Scale tries to determine how much control the students have in the classroom. Constructivist teaching leans towards student centred classrooms whereby they design and handle their own investigations, activities and discussions. The teacher plays a vital but backstage role which encourages students to become engaged, remain focussed and probe them with questions which will lead them to ideas, conclusions or further investigations.

The Student Negotiation Scale attempts to assess, from the teachers' perspective, how well the students collaborate with each other in the class. Students should be allowed to explain their opinions, provide suggestions, and reflect on and critique both their own ideas as well as others.

Finally the Attitudes Scale refers to how well students are engaged in activities, based on the teachers' opinion. The activities should address topics which excite and engage and make students aware of how relevant and meaningful the work is to them and to science. Both the student and teachers forms of CLES address all of these scales. The CLES is a useful instrument in assessing the level of constructivism being conducted in the classroom, from both the student and teacher perspective, as it may highlight any aspect of the teachers' practice that needs reform.

2.6 Teachers' Pedagogical Philosophy Interview (TPPI)

The Teachers' Pedagogical Philosophy Interview (TPPI) developed by Richardson and Simmons (1994) is used to determine teacher attitudes towards their own teaching ability and the values, beliefs and contexts creating that philosophy (see Appendix A.6). Studies which used TPPI include those by Eick and Reed (2002) and Luft (2001).

There are two types of TPPI; one aimed at new teachers in their first year of work and the other aimed at teachers in their second and third year (Office of Educational Research and Improvement (ED), 1997). It is advised that the interview should take place between the third and seventh month of the academic year. The TPPI for first year teachers consists of 44 Level 1 questions with the option of including 6 Level 2 questions. The TPPI for second and third year teachers includes 34 questions which include 15 Level 2 questions.

The results of the TPPI are analysed by grouping responses to headings about what occurs in the classroom (e.g. teacher/content, self as teacher, student actions, environment, context, diversity, philosophy of teaching) with headings about teacher style (e.g. traditional, transitional, conceptual, early constructivist, experienced constructivist, inquiry). Details of the analysis are given in references discussed above.

The TPPI interview was used in the SALISH I Research Project which aimed at promoting better science and mathematics teacher education. Eick and Reed (2002) also used this instrument when studying the effect of pre-service teachers' learning histories on their own method of instruction.

2.7 Science Teaching Inquiry Rubric (STIR)

The Science Teaching Inquiry Rubric (STIR), developed by Beerer and Bodzin (2003) can be used to assess teachers' level of inquiry based practices in the classroom. It is an observational tool that rates an elementary school teachers' classroom along the scale from teacher centred to student centred. This rubric (see Appendix A.7) is structured around the five essential features of classroom inquiry as put forward by the National Research Council (2000) and the level to which the teachers' practices move towards or away from this inquiry environment. These five features contain 5 subcategories containing statements that represent "Learner Centred" to "Teacher Centred" classroom practice (Table 5). STIR can be used as a valid observational tool, however, it isn't reliable enough for teachers to reflect on their own practices by using it as a self assessment tool. STIR is also discussed in another study by Beerer and Bodzin (2004).

Learner Centered ⟷ Teacher Centered

Learners are engaged by scientifically oriented questions.					
Teacher provides an opportunity for learners to engage with a scientifically oriented question.	Learner is prompted to formulate own questions or hypothesis to be tested.	Teacher suggests topic areas or provides samples to help learners formulate own questions or hypothesis.	Teacher offers learners lists of questions or hypotheses from which to select.	Teacher provides learners with specific stated (or implied) questions or hypotheses to be investigated.	No evidence observed.
Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.					
Teacher engages learners in planning investigations to gather evidence in response to questions.	Learners develop procedures and protocols to independently plan and conduct a full investigation.	Teacher encourages learners to plan and conduct a full investigation, providing support and scaffolding with making decisions.	Teacher provides guidelines for learners to plan and conduct part of an investigation. Some choices are made by the learners.	Teacher provides the procedures and protocols for the students to conduct the investigation.	No evidence observed.
Teacher helps learners give priority to evidence which allows them to	Learners determine what constitutes evidence and	Teacher directs learners to collect certain data, or only	Teacher provides data and asks learners to analyze.	Teacher provides data and gives specific direction on how	No evidence observed.

draw conclusions and/or develop and evaluate explanations that address scientifically oriented questions.	develop procedures and protocols for gathering and analyzing relevant data (as appropriate).	provides portion of needed data. Often provides protocols for data collection.		data is to be analyzed.	
Learners formulate explanations and conclusions from evidence to address scientifically oriented questions.					
Learners formulate conclusions and/or explanations from evidence to address scientifically oriented questions.	Learner is prompted to analyze evidence (often in the form of data) and formulate own conclusions / explanations.	Teacher prompts learners to think about how analyzed evidence leads to conclusions/explanations, but does not cite specific evidence.	Teacher directs learners' attention (often through questions) to specific pieces of analyzed evidence (often in the form of data) to draw conclusions and/or formulate explanations.	Teacher directs learners' attention (often through questions) to specific pieces of analyzed evidence (often in the form of data) to lead learners to predetermined correct conclusion / explanation (verification).	No evidence observed.
Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.					
Learners evaluate their conclusions and/or explanations in light of alternative conclusions/ explanations, particularly those reflecting scientific understanding.	Learner is prompted to examine other resources and make connections and/or explanations independently.	Teacher provides resources to relevant scientific knowledge that may help identify alternative conclusions and/or explanations. Teacher may or may not direct learners to examine these resources, however.	Teacher does not provide resources to relevant scientific knowledge to help learners formulate alternative conclusions and/or explanations. Instead, the teacher identifies related scientific knowledge that could lead to such alternatives, or suggests possible connections to such alternatives.	Teacher explicitly states specific connections to alternative conclusions and/or explanations, but does not provide resources.	No evidence observed.
Learners communicate and justify their proposed explanations.					
Learners communicate and justify their proposed conclusions and/or explanations.	Learners specify content and layout to be used to communicate and justify their conclusions and explanations.	Teacher talks about how to improve communication, but does not suggest content or layout.	Teacher provides possible content to include and/or layout that might be used.	Teacher specifies content and/or layout to be used.	No evidence observed.

Table 5: Elements of Science Teaching Inquiry Rubric (Beerer and Bodzin, 2003)

2.8 Views of Nature of Science (VNOS)

The Views of Nature of Science questionnaire (VNOS) developed by Abd-El-Khalick, Lederman, Bell & Schwartz (2001) is an open response instrument used with both students and primarily pre-service teachers, to determine their views on scientific knowledge and its development (see Appendix A.8). The questionnaire, together with individual interviews, covers the areas of:

- The Empirical Nature of Scientific Knowledge,
- Observation, Inference and Theoretical Entities in Science,
- Scientific Theories and Laws,
- The Creative and Imaginative Nature of Scientific Knowledge,
- The Subjective and Theory-laden Nature of Scientific Knowledge,
- The Social and Cultural Embeddedness of Scientific Knowledge,
- The Myth of the "Scientific Method,
- The Tentative Nature of Scientific Knowledge.

The development of VNOS has led to three separate, although similar, questionnaires; VNOS Form A, B and C. VNOS-A attempts to analyse second level students' views on the uncertain and indefinite aspects of the nature of science, or "The Tentative Nature of Scientific Knowledge". VNOS-B is a modified version of VNOS-A which is used with pre-service science teachers to understand their ideas of "the tentative, empirical, inferential, creative and subjective NOS" (Abd-El-Khalick, Lederman, Bell, & Schwartz, 2001). The VNOS-C is a modification of VNOS-B and was administered to third level undergraduates, graduates and pre-service science teachers. As well as the topics covered in VNOS-B, VNOS-C also introduced questions which would elucidate participants' views on "The Social and Cultural Embeddedness of Scientific Knowledge" and "The Myth of the "Scientific Method".

Once a participant has completed the VNOS questionnaire, the responses are summarised and then analysed for any particular patterns that can lead to creating a profile of the participant in question. Semi structured interviews are strongly encouraged to accompany the questionnaires to eliminate any misconceptions perceived from the original questionnaire transcripts. However with VNOS-B, researchers found over time that they became more adept at understanding participants' answers and there was less of a need to interview everyone so as to grasp exactly what each written response meant (Abd-El-Khalick, Lederman, Bell, & Schwartz, 2001). The interviews for VNOS-C were designed to get participants to elaborate on their responses as well as on "Observation, Inference and Theoretical Entities in Science", "Scientific Theories and Laws", and "The Social and Cultural Embeddedness of Scientific Knowledge". The results of the interviews are treated in the same manner as the questionnaires in that they are summarised, analysed and categorised and finally profiled. These profiles are then compared to those from the questionnaire and overall profiles are generated.

Other studies which have used VNOS include those by Schwartz, Lederman, & Crawford (2004) and Lederman (1992).

2.9 Teaching Science as Inquiry (TSI)

In order to understand how pre-service teachers can implement inquiry in their future classrooms it is necessary to examine their own pedagogical beliefs and whether they are confident and competent in inquiry methods. The Teaching Science as Inquiry (TSI) instrument (Appendix A.9) was developed by Smolleck, Zembal-Saul and Yoder (2006) to assess pre-service teachers' self efficacy in regards to using an inquiry approach in their science teaching. Many teachers have not experienced inquiry first hand in their own education and so it is important that they are exposed to and encouraged to use inquiry oriented practices before they graduate. Instilling a sense of confidence in teaching inquiry is crucial for pre-service teachers. Low self efficacy in scientific inquiry can lead teachers to avoid using this practice altogether. The TSI instrument assesses their stance on teaching inquiry and how comfortable they are with employing this method of instruction in the classroom. The TSI instrument consists of 69 items and participants are required to indicate their level of agreement with each statement. Additionally, behaviours are usually better predicted by self-efficacy beliefs than outcome expectations (Schunk & Miller, 2002). The TSI instrument contains 34 items that address personal self-efficacy and 35 items that address outcome expectancy. The 34 self-efficacy questions are divided among five sections which address the following essential features of classroom inquiry which are aligned with the five essential features recognized by the National Science Education Standards,(NRC, 2000):

1. Learner engages in scientifically oriented questions. (7 items)
2. Learner gives priority to evidence in responding to questions. (8 items)
3. Learner formulates explanations from evidence. (6 items)
4. Learner connects explanations to scientific knowledge. (6 items)
5. Learner communicates and justifies explanations (7 items)

Responses to the questions use a 5-point scale with *5 = Strongly Agree, 4 = Agree, 3= Uncertain, 2 = Disagree, and 1 = Strongly Disagree.* Responses to the survey items were summed to obtain a score for each participant. This score was divided by the number of items on the survey to obtain a mean score that reflects the level of self efficacy toward teaching science as inquiry. A 13-step process was used to develop and build validity and reliability into the TSI instrument (Smolleck, Zembal-Saul and Yoder, 2006).

2.10 Science Attitude Survey (SAS)

Damnjanovic (1999) studied the difference between in-service and pre-service science teachers' attitudes towards teaching inquiry in the classroom and identified a number of areas within their views of teaching contemporary science that distinguished the two groups from each other. A Science Attitude Survey (SAS) instrument to assess their differences in opinion was constructed using the three parameters, "Attitudes Toward Science", "Image of Science", and "Characteristics of Good Science Teachers and Teaching" (see Appendix A.10). The response differences between pre-service and in-service teachers on each of 25 statements on the Science Attitude Survey item were compared and discussed.

2.11 Other Instruments

Other sources have also provided information about teacher beliefs and approaches to inquiry based science education through the primary use of interviews. The Biomind programme, which encompasses the second level Biology course in Israel, is centred on inquiry based science education. Ten teachers from different schools took part in a study by Zion *et al.* (2007) and completed two semi structured private interviews. The first was conducted at the beginning of their students' inquiry investigations, and covered the teachers' approach to inquiry, the obstacles they encountered and the methods employed to solve these problems. The second set of interviews took place in the final stages of the inquiry process when students were writing up their work in reports and portfolios. The questions focussed on the teachers' views of the Biomind programme itself as well as revisiting questions from the first interview that needed further attention. The results of the interviews proved to be helpful in understanding the difficulties teachers face in an inquiry classroom, their attitudes to learning as a process, changes in inquiry topics, limitations of their own pedagogical and scientific content knowledge as well as the issues students encountered during the inquiry process. In addition to the interviews, a questionnaire was administered to participating teachers called "The Winding Paths of Inquiry" which asked questions about their students' inquiry projects and how they were conducted.

The instruments discussed in the previous sections to do not represent an exhaustive list of instruments used to profile teachers using inquiry-based practices. Many studies have relied on self constructed instruments and tools to determine teacher change which include surveys and questionnaires (Lehman, George, Buchanan, & Rush, 2006, Lotter, Harwood, & Bonner, 2007), interviews (Shepardson & Harbor, 2004, Laius, Kask, & Rannikmae, 2009, Zion, Cohen, & Amir, 2007), and observations of classroom practice (Wee, Shepardson, Fast, & Harbor, 2007, Shepardson & Harbor, 2004).

3. Differences between pre-service and in-service teachers

In Damnjanovic's (1999) study of the differences between in-service and pre-service science teachers' attitudes towards teaching inquiry in the classroom, a number of areas were identified within their views of teaching contemporary science that distinguished the two groups from each other. Responses from 73 pre-service students and 90 in-service teachers were compared from a total of 25 statements concerning three parameters, "Attitudes Toward Science", "Image of Science", and "Characteristics of Good Science Teachers and Teaching". In response to statements that science is relevant in their daily lives, that it promotes a sense of curiosity and that it would be fun to be a scientist, both pre-service and in-service teachers agreed, but in-service teachers tended to agree more strongly. Similarly, in-service teachers disagreed more strongly than pre-service teachers to the statements that science was exact, that they were not intelligent enough to be scientists and that a good science teacher knows the answers to all student questions. From this study, Damnjanovic (1999) concluded that in-service teachers are more open to inquiry and contemporary science instruction and that they have more of a grasp on evolving teaching methods than pre-service teachers.

Conversely, a study by Shim, Young and Paolucci (2010) suggested that pre-service teachers are more flexible and open to implementing inquiry and in-service teachers are less so. They tend to hold on to their more traditional methods of teaching despite their participation in professional development and the provision of inquiry classroom materials. Before a pre-service educational methods course was implemented the undergraduates held similar beliefs to in-service teachers about inquiry and the Nature of Science. After completing the module however, there was a clear distinction between the level of creativity pre-service teachers believed was a part of science in comparison to in-service teachers. In-service teachers, most of which used inquiry materials from professional development, tended to agree with statements such as "When scientists use the scientific methods correctly, their results are true and accurate", "Scientists' observations of the same event will be the same because observations are facts", "Scientific society is not influenced by society or culture" etc. Pre-service teachers held more inquiry oriented beliefs which were more in tune with the Nature of Science. They responded positively to statements such as, "Scientists use different types of methods to conduct scientific investigations", "Scientists use imagination and creativity when collecting data" and responded more negatively to "Scientists follow the same step-by-step scientific method".

Teachers' beliefs, attitudes and concerns about teaching are very prominent factors in how they behave in the classroom and how well they execute their task. These factors appear to differ across novice or pre-service teachers to experienced or expert teachers. Kagan (1992) compiled an excellent review of educational programmes designed for pre-service and beginning teachers to shed light on their views, beliefs and how they change over time. Previous education and pre-existing views of teaching tend to play a major role in pre-service teachers' ideas of their role in the classroom. Three studies in this review focussed on this topic (Calderhead & Robson, 1991, McDaniel, 1991, Weinstein, 1990 taken from Kagan, 1992) and suggested that pre-service teachers held firmly to teaching beliefs that were influenced strongly by role models from their own education. In-service teachers however, exhibit independence in how they teach and do not rely on the image of previous teachers to shape their roles in the classroom (Kwok-wai, 2004).

For pre-service teachers, the first year of teaching can be disillusioning in that it often fails to meet the standards they set both for themselves and their students. Weinstein (1990) indicated that pre-service teachers are often too optimistic about their future teaching careers which may lend a hand to their inexperience with the act of teaching itself. Kowk-wai (2004) noticed how over half of the teachers in his study agreed to feeling both optimistic and confident about their teaching skills before entering a teaching profession and in the beginning of their careers. After years of experience teachers admit that confidence and commitment to their profession increases, which is obviously a more grounded and informed view than that held by pre-service teachers.

Weinstein (1990) indicated also how pre-service teachers thought that in theory the most important aspect of teaching was the care of their pupils yet as Calderhead and Robson (1991) outlined, pre-service teachers appear too concerned with their own image and development as a teacher rather than the role their pupils would play in the classroom and how to accommodate them best. These ideas remained very resistant and largely failed to change throughout the course of their teacher education. According to Westerman (1991) this attitude changes with teaching experience. In this study 5 novice teachers were compared to 5 expert teachers. The novice teachers used very structured lessons dictated by lesson plans and paid little regard to adjusting the lessons to meet the needs of their pupils. Expert teachers on the other hand paid more attention to reflecting on proposed lessons in order to assist students to their full capacity. Fuller (1969) compiled research on the concerns of beginning teachers and how they changed over time. Analysis was conducted on student teachers over a few semesters of teaching practice, where counselling psychologists taped conversations between the student teachers and analysed them to see any major topics being discussed. It was found that student teachers were very preoccupied with their own adequacy in managing the classroom, as well as trying to become familiar with school politics and relations with parents. This constituted a strong concern with self, as defined by Fuller (1969). Conversely, over the period of 11 weeks student teachers became more concerned about their pupils and their development. Kwok-wai (2004) conducted a study on 246 in-service teachers to ascertain their perceptions and concerns about teaching. A Likert type questionnaire was administered examining all areas of their pedagogy including their conception of constructivist versus direct transmission views of teaching. Only 13.1% of these teachers felt that the more traditional method of instruction was more fitting with the role of a teacher compared to 51.6% who believed that student learning should be guided or facilitated by a teacher (Kwok-wai, 2004).

Assessing students' prior knowledge is an important factor in teaching through inquiry. Two pre-service teachers, two first-year teachers and two expert teachers were examined in a study by Meyer (2004) to identify any differences in both the way they understood prior knowledge and how they used this knowledge to make decisions in the classroom. They were interviewed initially on these topics, then their lessons were observed by a researcher to evaluate if prior knowledge was assessed effectively or at all. Following this the teachers took part in another informal interview to assess their view on how the class went. The results showed a number of things. Firstly, pre-service and first year teachers believed the source of prior knowledge was majorly from previously taught material in school. Expert teachers however, gave this little regard and instead believed that prior knowledge came from real life situations which students have experienced, learned or seen outside of school.

"They can explain or see what density does and how density works in real life situations. I think they have a sense of why certain things float and other things sink." (Meyer, 2004)

Prior knowledge in the view of the novice teachers was considered the basis to which teachers could build on the students' knowledge of science. By contrast the expert teachers had a more open view in that prior knowledge acts to connect newly acquired information with other concepts and real life situations. Another difference between novice and expert teachers is in their ability to assess their students' prior knowledge in the classroom. Upon asking students about their prior knowledge, novices focussed on learned content and only made students aware of what they didn't know in an attempt to provoke students to learn more. The pre-service and first-year teachers floundered when attempting to alter their strategies to ascertain further the students' prior knowledge. Expert teachers tried to reveal what students actually did understand and changed their instruction almost effortlessly based on this information. Pre-service and first year teachers were found to be far too preoccupied with covering content and how they themselves should act in the classroom. Expert teachers, having the benefit of experience were more focussed on their students and found it easier to determine their needs and how to amend their own instruction adequately.

Ghaith and Shaaban (1999) discuss "personal teaching efficacy" and "general teaching efficacy", taken from Anderson, Greene, and Lowen (1988), which constitute respectively, a), the personal expectations of a teacher in his/her classroom to promote student learning and b), that the ability of teachers in general is sufficient to overcome any problems within the school's control. They discuss how personal and general teacher efficacy are likely to increase in pre-service teachers through their course whereas on gaining experience their general efficacy falls and their personal efficacy increases. The concerns of beginning, experienced and highly experienced teachers were analysed through a questionnaire which divides teaching concerns into three categories, "Self-survival" items, "Task" items and "Impact" items. Self survival items correspond to the pressures of salary, classroom management, and interactions with parents, peers and superiors. Task items are more organisation based concerns referring to lesson plans and curriculum coverage throughout an academic year, and Impact items refer to concerns about promoting student learning. The results from this study showed how teachers with 15 years experience or more were less concerned with all three items compared to beginning and experienced teachers. This indicated the need for professional development designed to improve teacher efficacy may have more of an impact on less experienced teachers.

Specifically, three profiling tools have been used with pre-service teachers i.e. TPPI, TSI and VNOS and details of these profile tools are presented in Section 2.

Bibliography

Abd-El-Khalick, F., Lederman, N. G., Bell, R. L., & Schwartz, R. S. (2001). Views of Nature of Science Questionnaire (VNOS). Toward valid and meaningful assessment of learners conceptions of the Nature of Science. *Proceedings of the Annual Meeting of the Association for the Education of Teacher in Science.* Costa Mesa, CA.

Akcay, B. (2007). Effectiveness of professional development program on a teacher's learning to teach science as inquiry. *Asia-Pacific Forum on Science Learning and Teaching* , Vol. 8, Issue 2, Article 2.

Anderson, R., Greene, M., & Loewen, P. (1988). Relationships among teachers' and students' thinking skills, sense of efficacy, and student achievement. *The Alberta Journal of Educational Research* , Vol. 34, Issue no. 2, p.148-165.

Beerer, K. and Bodzin, A. (2004). How to develop inquiring minds. District implements inquiry-based science instruction. *Journal of Staff Development* , Vol. 25, No. 4, 43-47.

Beerer, K. and Bodzin, A. M. (2003). Promoting Inquiry Based Science Instruction: The Validation of the Science Teacher Inquiry Rubric (STIR). *Journal of Elementary Science Education* , Vo. 15, No. 2, 39-49.

Burry-Stock, J. A., & Oxford, R. L. (1993). *Expert Science Teaching Educational Evaluation Model (ESTEEM) for Measuring Excellence in Science Teaching For Professional Development.* Washington, DC: Office of Educational Research and Development (ED).

Calderhead, J., & Robson, M. (1991). Images of teaching: Student teachers' early conceptions of classroom practice. *Teaching and Teacher Education* , 7, pp.1-8.

Campbell, T., Abd-Hamid, N. H., & Chapman, H. (2010). Development of Instruments to Assess Teacher and Student Perceptions of Inquiry Experiences in Science Classrooms. *Journal of Science Education* , 21:13-30.

Crawford, B. (2000). Embracing the Essence of Inquiry: New Roles for Science Teachers. *Journal of Research in Science Teaching* , Vol. 37, No. (, PP. 916-937.

Damnjanovic, A. (1999). Attitudes Toward Inquiry-Based Teaching: Differences Between Preservice and In-service Teachers. *School Science and Mathematics* , PP:71-78.

Damnjanovic, A. (1999). Attitudes Toward Inquiry-Based Teaching: Differences Between Preservice and In-service Teachers. *School Science and Mathematics* , PP:71-78.

Eick, C. J., & Reed, C. (2002). What Makes an Inwuiry-Oriented Science Teacher? The Influence of Learning Histories on Student teacher Role Identity and Practice. *Science Teacher Education* , PP:401-406.

Fuller, F. F. (1969). Concerns of Teachers: A Developmental Conceptualization. *American Educational Research Journal* , Vol. 6, No. 2.

Ghaith, G., & Shaaban, K. (1999). The relationship between perceptions of teaching concerns, teacher efficacy, and selected teacher characterisitcs. *Teaching and Teacher Education* , 15: 487-496.

Kagan, D. M. (1992). Professional Growth Among Preservice and Beginning Teachers. *Review of Educational Reasearch* , Vol. 62, No. 2, pp. 129-169.

Kimble, L. L., Yager, R. E., & Yager, S. O. (2006). Success of a Professional Development Model in Assisting Teachers to Change Their Teaching to Match the More Emphasis Conditions Urged in the National Education Standards. *Journal of Science Teacher Education* .

King, D., Bellocchi, A., & Ritchie, S. M. (2008). Making Connections: Learning and Teaching Chemistry in Context. *Research in Science Education* , 365-384.

Kwok-wai, C. (2004). Teacher Professional Development: In-service Teacher s' Motives, Perceptions and Concerns about Teaching. *Hong Kong Teachers' Centre Journal* , Vol. 3, pp.56-71.

Laius, A., Kask, K., & Rannikmae, M. (2009). Comparing outcomes from two case studies on chemistry teachers' readiness to change. *Chemistry Education Research and Practice* , 142-153.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching* , Vol. 29, Issue 4, 331-359.

Lehman, J. D., George, M., Buchanan, P., & Rush, M. (2006). Preparing Teachers to Use Problem-centred, Inquiry-based Science: Lessons from a Four-Year Professional Development Project. *The Interdisciplinary Journal of Problem-based Learning* , Vol 1. No 1, PP:76-99.

Lotter, C., Harwood, W. S., & Bonner, J. J. (2007). The Influence of Core Teaching Conceptions on Teachers' Use of Inquiry Teaching Practices. *Journal of Research in Science Teaching* , Vol. 4, No. 9, 1318-1347.

Luft, J. A. (2001). Changing inquiry practices and beliefs: the impact of an inquiry-based professional development programme on beginning and experienced science teachers. *International Journal of Science Education* , Vol. 23, No. 5, 517-534.

McDaniel, J. E. (1991). Close encounters: How do student teachers make sense of the social foundations? *Paper presented at the Annual Meeting of the American Educational Research Association.* Chicago.

Meyer, H. (2004). Novice and Expert Teachers' Conceptions of learners Prior Knowledge. *Science Education* , Vol. 88, No. 6, pp.970-983.

National Research Council. (2000). *Inquiry and the National Science Education Standards: a guide for teaching and learning.* Washington, DC.: National Academy Press.

National Research Council. (1996). *National Science Education Standards.* Washington, D.C.: National Academy Press.

Office of Educational Research and Improvement (ED). (1997). *Secondary Science and Mathematics Teacher Preparation Programs: Influences on New teachers and Their Students. Instrument Package and User Guide.* Washington, D.C.

Organisation for Economic Co-operation and Development. (n.d.). *OECD Teaching and Learning International Survey (TALIS) Home*. Retrieved February 2011, from OECD Directorate for Education: http://www.oecd.org/document/0/0,3746,en_2649_33723_38052160_1_1_1_1,00.html

Organisation for Economic Co-operation and Development. (2010). *TALIS 2008 Technical Report.* Paris: OECD Publications.

Piburn, M. S. (2007, August 16). *Reformed Teaching Observational Protocol*. Retrieved April 18, 2011, from http://physicsed.buffalostate.edu/AZTEC/RTOP/RTOP_full/index.htm

Piburn, M., & Sawada, D. (2000). *Reformed Teaching Observational Protocol (RTOP): Reference Manual.* Tempe, AZ: ACEPT Technical Report No. INOO-3.

Schwartz, R. S., Lederman, N. G., & Crawford, B. A. (2004). Developing Views of the Nature of Science in an Authentic Context: An explicit Approach to Bridging the Gap Between Nature of Science and Scientific Inquiry. *Science Teacher Education* , Vol. 88, No. 4, 610-645.

Shepardson, D. P., & Harbor, J. (2004). ENVISION: the effectiveness of a dual-level professional development model for changing teacher practice. *Environmental Education Research* , Vol. 10, No. 4, P. 471-492.

Shim, M. K., Young, B. J., & Paolucci, J. (2010). Elementary Teachers' Views on the Nature of Scientific Knowledge: A Comparison of Inservice and Preservice Teachers Approach. *Electronic Journal of Science Education* , Vol. 14, No. 1.

Smolleck, L. D., Zembal-Saul, C., & Yoder, E. P. (2006). The Development of an Instrument to Measure Preservice Teachers' Self-Efficacy in Regard to The Teaching of Science as Inquiry. *Journal of Science Teacher Education* , 17:137-163.

Taylor, P. C., & Fraser, B. J. (1991). Development of an instrument for assessing constructivist learning environments. *Paper presented as the annual meeting of the American Research Association.* New Orleans, LA.

Taylor, P., Fraser, B., & Fisher, D. (1997). Monitoring constructivist classroom environments. *International Journal of Educational Research* , Vol. 27, No.4, 293-302.

Wee, B., Shepardson, D., Fast, J., & Harbor, J. (2007). Teaching and Learning about Inquiry: Insights and Challenges in Professional Development. *Journal of Science Teacher Education,* 18:63-69.

Weinstein, C. S. (1990). Prospective elementary teachers' beliefs about teaching: Implications for teacher education. *Teaching and Teacher Education* , 6, pp.279-290.

Westerman, D. M. (1991). Expert and Novice Teacher Descision Making. *Journal of Teacher Education* , Vol. 42, No. 4, pp. 292-305.

Zion, M., Cohen, S., & Amir, R. (2007). The Spectrum of Dynamic Inquiry. *Research in Science Education* , Vol 37, PP. 423-447.

Appendices

APPENDIX A.1 Teaching And Learning International Survey (TALIS)

APPENDIX A.2 Reformed Teaching Observation Protocol (RTOP)

APPENDIX A.3 Expert Science Teaching Evaluation Model (ESTEEM)

APPENDIX A.4 Principals of Scientific Inquiry-Teacher (PSI-T)

APPENDIX A.5 Constructivist Learning Environment Survey (CLES)

APPENDIX A.6 Teachers Pedagogical Philosophy Interview (TPPI)

APPENDIX A.7 Science Teacher Inquiry Rubric (STIR)

APPENDIX A.8 Views of the Nature of Science Questionnaire (VNOS)

APPENDIX A.9 Teaching Science as Inquiry (TSI)

APPENDIX A.10 Science Attitude Survey (SAS)

APPENDIX A.1Teaching and Learning International Survey (TALIS)

Taken from and developed by: Organisation and Co-Operation for Economic Development (OECD) as part of the Indicators for Education Systems Project (INES).

Section on Teaching Beliefs and Practices

Question 29				
We would like to ask you about your personal beliefs on teaching and learning. Please indicate how much you disagree or agree with each of the following statements				
Please mark one choice in each row	**Strongly disagree**	**Disagree**	**Agree**	**Strongly Agree**
a) Effective good teachers demonstrate the correct way to solve a problem				
b) When referring to a "poor performance", i mean a performance that lies below the previous performance level of the students				
c) It is better when the teacher – not the student – decides what activities are to be done.				
d) My role as a teacher is to facilitate students own inquiry.				
e) Teachers know a lot more than students; they shouldn't let students develop answers that may be incorrect when they can just explain the answers directly.				
f) Students learn best by finding solutions to problems on their own				
g) Instruction should be built around problems with clear, correct answers, and around ideas that most students can grasp quickly.				
h) How much students learn depends on how much background knowledge they have – that is why teaching facts is so necessary.				
i) Students should be allowed to think of solutions to practical problems themselves before the teacher shows them how they are solved.				
j) When referring to a "good performance", i mean a performance that lies above the previous achievement level of the student				
k) A quiet classroom is generally needed for effective learning.				
l) Thinking and reasoning processes are more important that specific curriculum content.				

Section on "Your teaching in a particular <class> at this school"

Question 42					
How often do each of the following activities happen in this <target class> throughout the school year?					
Please mark one choice in each row	**Never or hardly ever**	**In about one-quarter of <lessons>**	**In about one-half of <lessons>**	**In about three-quarters of <lessons>**	**In almost every lesson**
a) I present new topics to the class (lecture-style presentation).					
b) I explicitly state learning goals.					
c) I review with the students the homework they have prepared.					
d) Students work in small groups to come up with a joint solution to a problem or task.					
e) I give different work to the students that have difficulties learning and/or to those who can advance faster.					
f) I ask my students to suggest or to help plan classroom activities or topics					
g) I ask my students to remember every step in a procedure.					
h) At the beginning of the lesson i present a short summary of the previous lesson.					
i) I check my students' exercise books					
j) Students work on projects that require at least one week to complete.					
k) I work with individual students.					
l) Students evaluate and reflect upon their won work					
m) I check, by asking questions, whether or not the subject matter has been understood.					
n) Students work in groups based on their abilities.					
o) Students make a product that will be used by someone else.					
p) I administer a test or quiz to assess student learning.					
q) I ask my students to write an essay in which they are expected to explain their thinking or reasoning at some length.					
r) Students work individually with the textbook or worksheets to practice newly taught subject matter.					
s) Students hold a debate and argue for a particular point of view which may not be their own					

APPENDIX A.2 Reformed Teaching Observation Protocol (RTOP)

Taken from and developed by: Piburn, M., & Sawada, D. (2000). *Reformed Teaching Observational Protocol (RTOP): Reference Manual* . Tempe, AZ: ACEPT Technical Report No. INOO-3.

Background Information

Name of Teacher______________________ Announced Observation?______________________

Location of class____
(district, school, room)

Years of teaching______________________ Teaching Certification _________________________
(K-8 or 7-12)

Subject observed______________________ Grade Level___________________________________

Observer_____________________________ Date of Observation___________________________

Start Time____________________________ End Time_____________________________________

Contextual Background and Activities

In the space provided below please give a brief description of the lesson observes, the classroom setting in which the lesson took place (space, seating arrangements, etc.) and any relevant details about the students (number, gender, ethnicity) and teacher that you think are important. Use diagrams if they seem appropriate

Record here events that may help in documenting the ratings.

Time	Description of Events

I. Lesson Design and Implementation

Never Occurred Very Descriptive

1. The instructional strategies and activities respected students prior Knowledge and the preconceptions inherent therein.	0	1	2	3	4
2. The lesson was designed to engage students as members of a Learning community.	0	1	2	3	4
3. In this lesson, student exploration preceded formal presentation.	0	1	2	3	4
4. This lesson encouraged students to seek and value alternative Modes of investigation problem solving	0	1	2	3	4
5. The focus and direction of the lesson was often determined by ideas originating with the students.	0	1	2	3	4

II. Content

Propositional Knowledge

6. The lesson involved fundamental concepts of the subject.	0	1	2	3	4
7. The lesson promoted strongly conceptual understanding.	0	1	2	3	4
8. The teacher had a solid grasp of the subject matter content inherent in the lesson	0	1	2	3	4
9. Elements of abstraction (i.e. symbolic representations, theory Building) were encouraged when it was important to do so.	0	1	2	3	4
10. Connections with other content disciplines and/or real world Phenomena were explored and valued.	0	1	2	3	4

Procedural Knowledge

11. Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena.	0	1	2	3	4
12. Students made predictions, estimations and/or hypothesis and Devised means for testing them.	0	1	2	3	4
13. Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.	0	1	2	3	4
14. Students were reflective about their learning.	0	1	2	3	4
15. Intellectual rigor, constructive criticism, and the challenging of ideas were values	0	1	2	3	4

Continue recording salient events here

Time	Description of Events

III. Classroom Culture

Never Occurred — Very Descriptive

Communicative Interactions

16. Students were involved in the communication of their ideas to Others using a variety of means and media	0	1	2	3	4
17. The teacher's questions triggered divergent modes of thinking.	0	1	2	3	4
18. There was a high proportion of student talk and a significant amount of it occurred between and among students.	0	1	2	3	4
19. Student questions and comments often determined the focus and direction of classroom discourse.	0	1	2	3	4
20. There was a climate of respect for what others had to say.	0	1	2	3	4

Student/Teacher Relationships

21. Active participation of students was encouraged and valued.	0	1	2	3	4
22. Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence.	0	1	2	3	4
23. In general the teacher was patient with students.	0	1	2	3	4
24. The teacher acted as a resource person, working to support and enhance student investigations.	0	1	2	3	4
25. The metaphor "teacher as listener" was very characteristic of this classroom	0	1	2	3	4

Additional comments you may wish to make about this lesson

APPENDIX A.3 Expert Science Teaching Evaluation Model (ESTEEM)

Copy of this instrument is not available in literature. Authors have been contacted.

APPENDIX A.4 Principals of Scientific Inquiry-Teacher (PSI-T)

Taken from and developed by: Campbell, T., Abd-Hamid, N. H., & Chapman, H. (2010). Development of Instruments to Assess Teacher and Student Perceptions of Inquiry Experiences in Science Classrooms. *Journal of Science Education* , 21:13-30.

	Almost never	Seldom	Some-times	Often	Almost always
A. Asking questions/framing research questions: in the science classroom					
A1. Students formulate questions which can be answered by investigations					
A2. Student research questions are used to determine the direction and focus of the lab.					
A3. Students framing their own research questions are important					
A4. Time is devoted to refining student questions so that they can be answered by investigations					
B. Designing investigations: in the science classroom					
B1. Students are given step-by-step instructions before they conduct investigations					
B2. Students design their own procedures for investigations					
B3. Students engage in the critical assessment of the procedures that are employed when they conduct investigations					
B4. Students justify the appropriateness of the procedures that are employed when they conduct investigations					
C. Conducting investigations: in the science classroom					
C1. Students conduct their own procedures of an investigation					
C2. The investigation is conducted by the teacher in front of the class.					
C3. Students actively participate in investigations as they are conducted.					
C4. Each student has a role as investigations are conducted.					
D. Collecting data: in the science classroom					
D1. Students detemine which data to collect					
D2. Students take detailed notes during each investigation along with other data they collect.					
D3. Students understand why the data they are collecting is important.					
D4. Students decide when data should be collected in an investigation					
E. Drawing conclusions: in the science classroom					
E1. Students develop their own conclusions for investigations					
E2. Students consider a variety of ways of interpreting evidence when making conclusions					
E3. Students connect conclusions to scientific knowledge					
E4. Students justify their conclusions					

APPENDIX A.5 Constructivist Learning Environment Survey (CLES)

Taken from: Office of Educational Research and Improvement (ED). (1997). *Secondary Science and Mathematics Teacher Preparation Programs: Influences on New teachers and Their Students. Instrument Package and User Guide.* Washington, D.C.

Science Teacher Form

Date ______________________________ Teacher Name________________________________

School ____________________________ Course Title___________________________________

Directions: For each statement, fill in the circle that best describes your feelings about the class that was videotaped. Please consider each item carefully and answer every item.

In this class…..	Almost Always	Often	Sometimes	Seldom	Almost Never
1. Students learn about the world outside of school.	0	0	0	0	0
2. Students learn that scientific theories are human inventions.	0	0	0	0	0
3. It's OK for students to ask "Why do we have to learn this?"	0	0	0	0	0
4. Students help me to plan what they are going to learn.	0	0	0	0	0
5. Students get the chance to talk to each other.	0	0	0	0	0
6. Students look forward to the learning activities.	0	0	0	0	0
7. New learning starts with problems about the world outside of school.	0	0	0	0	0
8. Students learn that science is influenced by people's values and opinions.	0	0	0	0	0
9. Students feel free to question the way they are being taught.	0	0	0	0	0
10. Students help the teacher decide how well their learning is going.	0	0	0	0	0
11. Students talk with each other about how to solve problems.	0	0	0	0	0
12. The activities are among the most interesting at this school.	0	0	0	0	0
13. Students learn how science can be a part of their out-of-school life.	0	0	0	0	0
14. Students learn that the views of science have changed over time.	0	0	0	0	0

In this class….. Almost Often Sometimes Seldom Almost

	Always				Never
15. It's OK for students to complain about activities that are confusing.	0	0	0	0	0
16. Students have a say in deciding the rules for classroom discussion.	0	0	0	0	0
17. Students try to make sense of each other's ideas.	0	0	0	0	0
18. The activities make students interested in science.	0	0	0	0	0
19. Students get a better understanding of the world outside of school.	0	0	0	0	0
20. Students learn that different sciences are used by people in other cultures.	0	0	0	0	0
21. It's OK for students to complain about anything that stops them from learning.	0	0	0	0	0
22. Students have a say in deciding how much time they spend on an activity.	0	0	0	0	0
23. Students ask each other to explain their ideas.	0	0	0	0	0
24. Students enjoy the learning activities.	0	0	0	0	0
25. Students learn interesting things about the world outside of school.	0	0	0	0	0
26. Students learn that scientific knowledge can be questioned.	0	0	0	0	0
27. Students are free to express their opinions.	0	0	0	0	0
28. Students offer to explain their ideas to one another.	0	0	0	0	0
29. Students feel confused.	0	0	0	0	0
30. What students learn has nothing to do with their out-of-school life.	0	0	0	0	0
31. Students learn that science reveals the secrets of nature.	0	0	0	0	0
32. It's OK for students to speak up for each other's rights.	0	0	0	0	0
33. Students have a say in deciding what will be on the test.	0	0	0	0	0
34. Students explain their ideas to each other.	0	0	0	0	0
35. The learning activities are a waste of time.	0	0	0	0	0
36. Students have a say in deciding what activities they do.	0	0	0	0	0
37. What students learn has nothing to do with the world outside of school.	0	0	0	0	0
38. Students learn that scientific knowledge is beyond doubt.	0	0	0	0	0
39. Students feel unable to complain about anything.	0	0	0	0	0
40. Students have a say in deciding **how** their learning is assessed.	0	0	0	0	0
41. Students pay attention to each other's ideas.	0	0	0	0	0
42. Students feel tense.	0	0	0	0	0

APPENDIX A.6 Teachers Pedagogical Philosophy Interview (TPPI)

Developed by: Lon Richardson and Patricia Simmons (1994).
Taken from: Office of Educational Research and Improvement (ED). (1997). *Secondary Science and Mathematics Teacher Preparation Programs: Influences on New teachers and Their Students. Instrument Package and User Guide.* Washington, D.C.

TPPI for First Year Teachers

Level I Interview Questions

1. How would you describe yourself as a classroom teacher?
2. What role model do you have for yourself as a classroom teacher?
3. Describe a well-organized classroom. When you have your classroom running the way you want it, what is it like?
4. How did you form this model of the well-organized classroom?
5. How long did it take you to develop this model of teaching?
6. What do you consider to be the founding principles of teaching? If you had to write a book describing the principles that teaching should be built on, what would those principles be?
7. How do you learn best?
8. How do you know when you have learned?
9. How do you know when you know something?
10. What are facts, laws, and theories in science/mathematics?
11. How are facts arrived at?
12. How do you distinguish among facts, laws, and theories in science/mathematics?
13. When you picture a good learner in your mind, what characteristics of that person lead you to believe that they are a good learner?
14. What is science/mathematics?
15. In what ways do you learn science/mathematics best?
16. When you learn science/mathematics, is it different than learning mathematics/science or
17. What are the founding principles of science/mathematics?
18. How do you decide what to teach and what not to teach?
19. How do you decide when to move from one concept to another?
20. What learning in your classroom do you think will be valuable to your students outside the classroom environment?
21. Describe the best teaching/learning situation that you have ever experienced.
22. In what way do you try to model that best teaching/learning situation in your classroom?
23. What are some of the impediments or constraints for implementing that kind of model in your classroom?
24. What are some of the tactics you use to overcome these constraints?
25. Are there any things at the local/school/state levels that influence the way you teach? What are some examples of this?
26. What are values?
27. How do you arrive at these values?
28. What are some of the things you value most about science/mathematics?
29. How do you believe your students learn best?

30. How do you know when your students understand a concept?
31. How do you know when learning is occumng, or has occurred in your classroom?
32. How do you think your students come to believe in their minds that they understand something?
33. In what ways do you manipulate the educational environment (classroom, school, etc.) to maximize student understanding?
34. What science/mathematics concepts do you believe are the most important for your students to understand by the end of the school year?
35. How do you want your students to view science/mathematics by the end of the school year?
36. What values do you want to develop in your students?
37. What are some of the things you believe your students value most about their educational experience in your classroom? When they leave here they say, 'I really liked (his/her) class because____________________
38. How do you accommodate students with special needs in your classroom?
39. What do you believe are your main strengths as a teacher?
40. In what areas would you like to improve as a teacher?
41. When did you realize you were becoming a good teacher, understanding that you were having a positive effect on your students and satisfied that you were doing the right thing?

42a. Were your undergraduate education/pedagogy courses beneficial to you when you began teaching? Why or why not?

42b. Were your undergraduate science/mathematics courses beneficial to you when you began teaching? Why or why not?

43a. What changes would you make in undergraduate education/pedagogy courses, if you could, to make the experience more meaningful?

43b. What changes would you make in undergraduate science/mathematics courses, if you could, to make the experience more meaningful?

44. In reference to the teaching model or teaching package that you have developed ..... if you had to divide that up into a pie chart, how much of that chart would come from undergraduate training, graduate training, your on-the-job experience, or anything else that you can think of?

Level II Interview Questions

45. How do you define truth?
46. Is there a relationship between science/mathematics and truth? What is that relationship (if yes)?
47. How do you define technology?
48. Is there a relationship between science/mathematics and technology? What is that relationship (if yes)?
49. How do you define society?
50. Is there a relationship between science/mathematics and society? What is that relationship (if yes)?

Teachers Pedagogical Philosophy Interview (TPPI)

Developed by: Lon Richardson and Patricia Simmons (1994).
Taken from: Office of Educational Research and Improvement (ED). (1997). *Secondary Science and Mathematics Teacher Preparation Programs: Influences on New teachers and Their Students. Instrument Package and User Guide.* Washington, D.C.

TPPI for Second and Third Year Teachers

Level I Interview Questions

1. How would you describe yourself as a classroom teacher?
2. What role model do you have for yourself as a classroom teacher?
3. Describe a well organized classroom. When you have your classroom running the way you want it, what is it like?
4. How did you form this model of the well-organized classroom?
5. How long did it take you to develop this model of teaching?
6. Now that you have more teaching experience, what do you consider to be the founding principles of teaching? If you had to write a book describing the principles that teaching should be built on, what would those principles be?
7. How do you learn best?
8. How do you know when you have learned?
9. How do you know when you know something?
10. When you picture a good learner in your mind, what characteristics of that person lead you to believe that they are a good learner?
11. How do you decide what to teach and what not to teach?
12. How do you decide when to move from one concept to another?
13. What learning in your classroom do you think will be valuable to your students outside the classroom environment?
14. Describe the best teaching/learning situation that you have ever experienced.
15. In what way do you try to model that best teaching/learning situation in your classroom?
16. What are some of the impediments or constraints of implementing that kind of model in your classroom?
17. What are some of the tactics you use to overcome these constraints?
18. Are there any things at the 1odschooVstate levels that influence the way you teach? What are some examples of this?
19. How do you believe your students learn best?
20. How do you know when your students understand a concept?
21. How do you know when learning is occurring or has occurred in your classroom?
22. In what ways do you manipulate the educational environment to maximize student understanding?
23. What science/mathematics concepts do you believe are the most important for your students to understand by the end of the school year?
24. How do you want your students to view science/mathematics by the end of the school year?
25. What values do you want to develop in your students?
26. What are some of the things you believe your students value most about their educational experience in your classroom? When they leave here they say, 'I really liked (his/her) class because__________

27. How would you compare your approach to teaching this year to last year's approach? Why is it the same/different?
28. How do you accommodate students with special needs in your classroom?
29. What do you believe are your main strengths as a teacher?
30. In what areas would you like to improve as a teacher?
31. When did you realize you were becoming a good teacher, understanding that you were having a positive effect on your students and satisfied that you were doing the right thing?

32a. Were your undergraduate education/pedagogy courses beneficial to you when you began teaching? Why or why not?

32b. Were your undergraduate science/mathematics courses beneficial to you when you began teaching? Why or why not?

33a. What changes would you make in undergraduate education/pedagogy courses, if you could, to make the experience more meaningful?

33b. What changes would you make in undergraduate science/mathematics courses, if you could, to make the experience more meaningful?

34. In reference to the teaching model or teaching package that you have developed .....if you had to divide that up into a pie chart, how much of that chart would come from undergraduate training, graduate training, your on-the-job experience, or anything else that you can think of?
35. What are facts, laws, and theories in science/mathematics?
36. How are facts arrived at?
37. How do you distinguish among facts, laws, and theories in science/mathematics?
38. What is science/mathematics?
39. In what ways do you learn science/mathematics best?
40. When you learn science/mathematics, is it different than learning mathematics/science or history?
41. What are the founding principles of science/mathematics?
42. What are values?
43. How do you arrive at these values?
44. What are some of the things you value most about science/mathematics?
45. Is there a relationship between science/mathematics and truth? What is that relationship (if yes)?
46. How do you define technology?
47. Is there a relationship between science/mathematics and technology? What is that relationship (if yes)?
48. How do you define society?
49. Is there a relationship between science/mathematics and society? What is that relationship (if yes)?

APPENDIX A.7 Science Teacher Inquiry Rubric (STIR)

Taken from and developed by: Beerer, K. and Bodzin, A. (2003). Promoting inquiry-based science instruction: The validation of the Science Teacher Inquiry Rubric (STIR). Journal of Elementary Science Education, 15(2), 39-49.

Directions: Reflect on the science lesson that you taught today. In your reflection, consider each of the following categories and the six statements on the left, written in bold. After looking at each bold statement, assess today's science instruction based on the categories delineated for statement. Place one "X' in the corresponding cell for each bold-faced statement. If there is no evidence of one of the statements in today's lesson, place a slash through the bold-faced statement. When you are finished, you should have 6 total responses.

Learner Centered ↔ Teacher Centered

Learners are engaged by scientifically oriented questions.					
Teacher provides an opportunity for learners to engage with a scientifically oriented question.	Learner is prompted to formulate own questions or hypothesis to be tested.	Teacher suggests topic areas or provides samples to help learners formulate own questions or hypothesis.	Teacher offers learners lists of questions or hypotheses from which to select.	Teacher provides learners with specific stated (or implied) questions or hypotheses to be investigated.	No evidence observed.
Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.					
Teacher engages learners in planning investigations to gather evidence in response to questions.	Learners develop procedures and protocols to independently plan and conduct a full investigation.	Teacher encourages learners to plan and conduct a full investigation, providing support and scaffolding with making decisions.	Teacher provides guidelines for learners to plan and conduct part of an investigation. Some choices are made by the learners.	Teacher provides the procedures and protocols for the students to conduct the investigation.	No evidence observed.
Teacher helps learners give priority to evidence which allows them to draw conclusions and/or develop and evaluate explanations that address scientifically oriented questions.	Learners determine what constitutes evidence and develop procedures and protocols for gathering and analyzing relevant data (as appropriate).	Teacher directs learners to collect certain data, or only provides portion of needed data. Often provides protocols for data collection.	Teacher provides data and asks learners to analyze.	Teacher provides data and gives specific direction on how data is to be analyzed.	No evidence observed.
Learners formulate explanations and conclusions from evidence to address scientifically oriented questions.					
Learners formulate conclusions and/or explanations from evidence to address scientifically oriented questions.	Learner is prompted to analyze evidence (often in the form of data) and formulate own conclusions / explanations.	Teacher prompts learners to think about how analyzed evidence leads to conclusions/explanations, but does not cite specific evidence.	Teacher directs learners' attention (often through questions) to specific pieces of analyzed evidence (often in the form of data) to draw conclusions and/or formulate explanations.	Teacher directs learners' attention (often through questions) to specific pieces of analyzed evidence (often in the form of data) to lead learners to predetermined correct conclusion / explanation (verification).	No evidence observed.

Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.					
Learners evaluate their conclusions and/or explanations in light of alternative conclusions/ explanations, particularly those reflecting scientific understanding.	Learner is prompted to examine other resources and make connections and/or explanations independently.	Teacher provides resources to relevant scientific knowledge that may help identify alternative conclusions and/or explanations. Teacher may or may not direct learners to examine these resources, however.	Teacher does not provide resources to relevant scientific knowledge to help learners formulate alternative conclusions and/or explanations. Instead, the teacher identifies related scientific knowledge that could lead to such alternatives, or suggests possible connections to such alternatives.	Teacher explicitly states specific connections to alternative conclusions and/or explanations, but does not provide resources.	No evidence observed.
Learners communicate and justify their proposed explanations.					
Learners communicate and justify their proposed conclusions and/or explanations.	Learners specify content and layout to be used to communicate and justify their conclusions and explanations.	Teacher talks about how to improve communication, but does not suggest content or layout.	Teacher provides possible content to include and/or layout that might be used.	Teacher specifies content and/or layout to be used.	No evidence observed.

APPENDIX A.8 Views of the Nature of Science Questionnaire (VNOS)

Taken from and developed by: Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learner's conceptions of nature of science. *Journal of Research in Science Teaching*, 39(6), 497-521.

<u>VNOS-A:</u>

1. After scientists have developed a theory (e.g., atomic theory), does the theory ever change? If you believe that theories do change, explain why we bother to learn about theories. Defend your answer with examples.
2. What does an atom look like? How do scientists know that an atom looks like what you have described or drawn?
3. Is there a difference between a scientific theory and a scientific law? Give an example to illustrate your answer.
4. How are science and art similar? How are they different?
5. Scientists perform scientific experiments/investigations when trying to solve problems. Do scientists use their creativity and imagination when doing these experiments/investigations?
6. Is there a difference between scientific knowledge and opinion? Give an example to illustrate your answer.
7. Some astrophysicists believe that the universe is expanding while others believe that it is shrinking; still others believe that the universe is in a static state without any expansion or shrinkage. How are these different conclusions possible if all of these scientists are looking at the same experiments and data?

<u>VNOS B:</u>

1. After scientists have developed a theory (e.g. atomic theory), does the theory ever change? If you believe that theories do change, explain why we bother to teach scientific theories. Defend your answer with examples.
2. What does an atom look like? How certain are scientists about the nature of the atom? What specific evidence do you think scientists use to determine what an atom looks like?
3. Is there a difference between a scientific theory and a scientific law? Give an example to illustrate your answer.
4. How are science and art similar? How are they different?
5. Scientists perform experiments/investigations when trying to solve problems. Other than the planning and design of these experiments/investigations, do scientists use their creativity and imagination during and after data collection? Please explain you answer and provide examples if appropriate.
6. Is there a difference between scientific knowledge and opinion? Give an example to illustrate your answer.
7. Some astronomers believe that the universe is expanding while others believe that it is shrinking; still others believe that the universe is in a static state without any expansion or shrinkage. How are these different conclusions possible if all of these scientists are looking at the same experiments and data?

VNOS-C:

1. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?
2. What is an experiment?
3. Does the development of scientific knowledge require experiments? If yes, explain why. Give an example to defend your position. If no, explain why. Give an example to defend your position.
4. After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change? If you believe that scientific theories do not change, explain why. Defend your answer with examples. If you believe that scientific theories do change: (a) Explain why theories change; (b) Explain why we bother to learn scientific theories. Defend your answer with examples.
5. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.
6. Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting the nucleus. How certain are scientists about the structure of the atom? What specific evidence do you think scientists used to determine what an atom looks like?
7. Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring. How certain are scientists about their characterization of what a species is? What specific evidence do you think scientists used to determine what a species is?
8. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypothesis formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?
9. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.
   If you believe that science reflects social and cultural values, explain why. Defend your answer with examples. If you believe that science is universal, explain why. Defend your answer with examples.
10. Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations? If yes, then at which stages of the investigations do you believe scientists use their imagination and creativity: planning and design, data collection, after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate. If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.

APPENDIX A.9 Teaching Science as Inquiry (TSI)

Teaching Science as Inquiry (TSI) Instrument

Please indicate the degree to which you agree or disagree with each statement below by circling in the appropriate number as indicated: 5 = Strongly Agree 4 = Agree 3 = Uncertain 2 = Disagree 1 = Strongly Disagree

Please indicate the degree to which you agree or disagree with each statement below by circling in the appropriate number as indicated below:

When I teach science…

	Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
1. I am able to offer multiple suggestions for creating explanations from data.	5	4	3	2	1
2. I am able to provide students with the opportunity to construct alternative explanations for the same observations.	5	4	3	2	1
3. I am able to encourage my students to independently examine resources in an attempt to connect their explanations to scientific knowledge.	5	4	3	2	1
4. I possess the ability to provide meaningful common experiences from which predictable scientific questions are posed by students.	5	4	3	2	1
5. I have the necessary skills to determine the best manner through which children can obtain scientific evidence.	5	4	3	2	1
6. I am able to provide opportunities for students to become the critical decision makers when evaluating the validity of scientific explanations.	5	4	3	2	1
7. I am able to guide students in asking scientific questions that are meaningful.	5	4	3	2	1
8. I am able to provide opportunities for my students to describe their investigations and findings to others using their evidence to justify explanations and how data was collected.	5	4	3	2	1
9. I am able to negotiate with students possible connections between/among explanations.	5	4	3	2	1
10. I encompass the ability to encourage students to review and ask questions about the results of other students' work.	5	4	3	2	1
11. I am able to guide students toward appropriate investigations depending on the questions they are attempting to answer.	5	4	3	2	1
12. I am able to create the majority of the scientific questions needed for students to investigate.	5	4	3	2	1
13. I possess the ability to allow students to devise their own problems to investigate.	5	4	3	2	1
14. I am able to play the primary role in guiding the identification of scientific questions.	5	4	3	2	1
15. I am able to guide students toward scientifically accepted ideas upon which they can develop more meaningful understanding of science.	5	4	3	2	1
16. I possess the abilities necessary to provide students with the possible connections between scientific knowledge and their explanations.	5	4	3	2	1
17. I possess the skills necessary for guiding my students toward explanations that are consistent with experimental and observational evidence.	5	4	3	2	1

When I teach science…

	Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree

18. I am able to encourage students to gather the appropriate data necessary for answering their questions.	5	4	3	2	1
19. I am able to offer/model approaches for generating explanations from evidence.	5	4	3	2	1
20. I am able to coach students in the clear articulation of explanations.	5	4	3	2	1
21. Through the process of sharing explanations, I am able to provide students with the opportunity to critique explanations and investigation methods.	5	4	3	2	1
22. I am able to facilitate open-ended, long-term student investigations in an attempt to provide opportunities for students to gather evidence.	5	4	3	2	1
23. I am able to help students refine questions posed by the teacher or instructional materials, so they can experience both interesting and productive investigations.	5	4	3	2	1
24. I am able to provide demonstrations through which students can focus their queries into manageable questions for investigation.	5	4	3	2	1
25. I am able to utilize worksheets as an instructional tool for providing a data set and walking students through the analysis process.	5	4	3	2	1
26. I am able to model for my students prescribed steps or procedures for communicating scientific results to the class.	5	4	3	2	1
27. I am able to provide my students with possible connections to scientific knowledge through which they can relate their explanations.	5	4	3	2	1
28. I am able to provide my students with evidence to be analyzed.	5	4	3	2	1
29. I am able to provide my students with the data needed to support an investigation.	5	4	3	2	1
30. I am able to provide my students with all evidence required to form explanations through the use of lecture and textbook readings.	5	4	3	2	1
31. I am able to model for my students the guidelines to be followed when sharing and critiquing explanations.	5	4	3	2	1
32. I am able to instruct students to independently evaluate the consistency between their own explanations and scientifically accepted ideas.	5	4	3	2	1
33. I am able to construct with students the guidelines for communicating results and explanations.	5	4	3	2	1
34. I am able to provide my students with explanations.	5	4	3	2	1

APPENDIX A.10 Science Attitude Survey (SAS)

Taken from and developed by: Damnjanovic, A. (1999). Attitudes Toward Inquiry-Based Teaching: Differences Between Preservice and In-service Teachers. *School Science and Mathematics* p71-78.

	Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree
1. Scientists believe they can find explanations for what they observe by looking at natural phenomena.	1	2	3	4	5
2. A scientific theory may not be entirely correct, but it is the best explanation scientists put forth.	1	2	3	4	5
3. Explanations put forth by the scientific community cannot be questioned by an ordinary citizen.	1	2	3	4	5
4. Science is relevant to my everyday life.	1	2	3	4	5
5. Science is exact.	1	2	3	4	5
6. There can never be more than one explanation for any naturally occurring phenomena.	1	2	3	4	5
7. Science fosters my feeling of curiosity.	1	2	3	4	5
8. Science is supposed to be boring.	1	2	3	4	5
9. Women cannot be scientists.	1	2	3	4	5
10. Most scientists are attractive people.	1	2	3	4	5
11. Most scientists have a keen sense of fashion.	1	2	3	4	5
12. Most scientists are forgetful.	1	2	3	4	5
13. Most scientists are eccentric.	1	2	3	4	5
14. Scientists are shy.	1	2	3	4	5
15. Most scientists are single.	1	2	3	4	5
16. It would be fun to be a scientist.	1	2	3	4	5
17. Scientific explanations can only be given by real scientists.	1	2	3	4	5
18. I am not smart enough to be a scientist.	1	2	3	4	5
19. A good science teacher asks questions that make students think.	1	2	3	4	5
20. A good science teacher encourages questions.	1	2	3	4	5
21. A good science teacher asks divergent type questions.	1	2	3	4	5
22. A good science teacher lectures a lot.	1	2	3	4	5
23. A good science teacher helps students memorize the information they need to know for the test.	1	2	3	4	5
24. A good science teacher has answers to all the questions students have about science.	1	2	3	4	5
25. A good science teacher joins the student in learning.	1	2	3	4	5