Teacher Educators' Conceptualisations and Practices towards Inquiry Based Science Teaching: a renewed research framework.

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Abstract: Currently European teachers have to develop inquiry based science teaching [IBST] in order to enhance pupils' learning and motivation towards scientific objects. Such teaching approaches are learning-focused, and appear more complex than content-centred methods. This paper focuses on 8 science teachers who are involved both within professional networks and with part time in service teacher education about IBST. It aims to identify their conceptualisations and practices, and particularly about their way to cope with pupils' diversity.

Key words: teacher development, teacher collaboration, teaching approaches, science education

European science teachers are expected to implement inquiry based science teaching [IBST] in order to enhance pupils' learning and motivation towards scientific objects (Rocard et al., 2007). Such teaching approaches which are learning-focused appear more complex than content-centred methods. In order to understand how teachers could master this complexity this paper focuses on 8 science teachers who are involved within continuing professional development [CPD] program promoting teacher collaboration through exchanges amongst professional network and carrying out in-service teaching education sessions for colleagues. Their conceptions and practices will be compared to 4 ordinary science teachers' who could only apply on their own experience.

1. The lack of teacher confidence for IBST methods

According to many European projects[1], IBST approach combines four main specifications:

- authentic and problem based learning activities where there may not be a correct answer
- a certain amount of experimental procedures, experiments and "hands on" activities, including searching for information
- self-regulated learning sequences where student autonomy is emphasised
- discursive argumentation and communication with peers ("talking science").

(Doris Jorde & Olsen Moberg, 2010, p. 3)

A round of seminars within the 15 European countries organized within S-TEAM project shows that in any national curriculum, such specifications consist of rules which could be narrowly applied by teachers. In fact, they combine plural elements which are interwoven and consist only of directions for actions which offer a wild scope of autonomy for teachers and students. Overcoming such complexity causes both an enthusiastic involvement for few teachers and a lack of confidence for a large amount of others. In order to disseminate IBST we need to make teachers more confident in their own capacity to be open to changes in the direction of science teaching methods.

This paper addresses a methodology for identifying and assessing IBST methods. It consists in elaborating a renewed research framework which considers the IBST genuine complexity. It aims to allow teachers and teacher educators to situate their activities with respect to an accurate model. The point is to enhance actors' confidence by providing them with a model which is accurate and could support teaching improvement.

2. A 6 dimensions model describing IBST methods

1.1. The 4 stages of professional development

Research about professional development shows that it consists of progressive and repeated reorganisations of the conceptualisations and practices, of the ways to think about activity and to act professionally (Boreham & Morgan, 2004; Engeström, 2001; Grangeat & Gray, 2007). Four stages are often identified as a continuum which underlines professional development: novice, advanced beginner, proficient performer, and expert (H. L. Dreyfus & S. E. Dreyfus, 1986).

[1] Mind The Gap and S-TEAM, for instance

During the two first stages, actors endeavour to elaborate meaningful units which gather and synthetize the different elements resulting from previous experience, discussions with other actors and knowledge resulting from education or training programs. Such units are identified as work process knowledge [WPK] within the industrial field by Boreham (2002). Such WPK organizes and orders 4 elements: actors' objects, clues picked up from the situation in order to diagnose the case, set of actions which results from this diagnostic, and professional knowledge used as reference to justify these actions (Grangeat, 2010). These set of 4 elements could be called '*teacher work process-knowledge'* [TWPK]. These actors are centred on their own activity.

During the two following stages, actors are able to match situations which appear similar and necessitate the same way to a ct. Thus, they can beneficiate of previous professional knowledge in order to achieve more challenging tasks and to cope with variations occurring amongst these. Consequently they reinforce the set of their TWPK by gathering similarities and distinguishing specificities through new wide cognitive units we could call '*teacher activity system*' [TAS] following Engeström (2000). These actors are centered both on pupils and colleagues activity; they connect their own conceptualizations and practices both with learners' ways to act in school and with their colleagues' teaching approaches.

Consequently, the following model must include the main dimensions of IBST. On each dimension it needs to identify 4 stages: the first two stages would be content and teacher centred and the last ones would be learning focused. We assume that the latter approach includes the former: the learners-centred approach is more sophisticated and complex than the teacher-centred (Grangeat, 2008; Hudson, 2007).

1.2. An IBST 6 dimensions model

A 6 dimensions model results from the IBST state of the art conducted by S-TEAM project.

1.2.1. Origin of questioning

The first dimension is about the origin of questioning which triggers the inquiry. On the first stage, teachers could elaborate the questioning on their own and manage to transform it into a learners questioning. On the last stage this questioning could be elaborate by pupils' group.

1.2.2. Nature of problem

The second dimension tackles the nature of the problem which supports and orientates the investigation. On one hand, the problem is closed and pupils have to follow a narrow protocol. On the other hand, the problem is open-ended and the learners need to elaborate their own hypothesis and protocol.

1.2.3. Promoting pupils' responsibility within the inquiry process

The third dimension addresses the responsibility of the leaners to carry out the inquiry process. On the first stages, teachers steer quite narrowly the investigation, for example by leading all the pupils' team towards a same experimentation. On the last, teachers manage to let a part of their responsibility to the learners, for example through providing them self-assessment documents.

1.2.4. Considering positively pupils' diversity

This dimension addresses the way teachers take into account of and cope with pupils' diversity of knowledge, needs, and motivation with respect of science learning. With respect of the current model, the first stages which are teacher-centred aim to cope with specific pupils' behaviour in order to involve them within the inquiry. The following stages –learners-centred– consist in adapting teaching strategy to the learners specificity.

1.2.5. Development of argumentation

The fifth dimension tackles the argumentation development. The first stages aim to facilitate discussion amongst pupils within the teams. The following stages aim to enable pupils to justify their conclusion with respect of experimental or database searching results.

1.2.6. Explanation of teachers' goals and strategies

This sixth and last dimension aims to make explicit the teacher's goals and specifically the learning outcomes which are expecting through IBST. The first stages consist in communicating to the students the teacher's expectations for the current lesson. The last stages aim to make explicit knowledge and meta-knowledge which result from the current session and will be useful within further situation and problem.

1.3. Understanding IBST through a 6 dimensions model

This model could allow us to describe and compare teachers' practices and approaches. Nevertheless, this paper's main purpose consists in overcoming IBST complexity through a model both referring to current research about science education. This 6 dimensions model endeavours to achieve these goals in order to able teachers to be more confident facing the changes resulting from IBST development within class-room.

2. Comparing teachers' activities through the IBST 6 dimensions model

2.1. Two groups of science teachers

In order to understand the effects of CPD 14 science teachers [ST] split in two groups are compared. They teach mathematics, biology, physics and chemistry, or technology.

The first group gathers 8 science teachers who are involved within CPD program through two activities: they frequently meet together and with local authorities in order both to improve their teaching approaches and practices, and to design and to carry out CPD program about IBST; we called it committed science teachers [CST]. The second group gathers 4 ordinary science teachers [OST] who could only apply on their own experience since they are involved neither within professional networks, nor within CPD program about IBST.

2.2. Data collecting

The data are collected through videotaped IBST sessions and interviews with each ST about the video. Firstly the research team ask each ST to carry out a lesson which he or she considers as IBST session. The lesson lasts for about 55 minutes. Afterwards, each ST is interviewed about the 20 last minutes of the video. The ST is asked to stop the video when an event which had conducted him or her to choose amongst different alternatives occurs. Thus, the ST is asked to make explicit both the event which challenged her teaching strategy, and the goals which steer the observed action; mostly, teachers explain professional knowledge which had underpinned their choices. The interviewer could also stop the video and ask questions. Such a methodology makes reachable the set of TWPK of each ST. Each interview lasts about 60 minutes. All lessons and interviews are transcribed and analysed in order to find out the 4 elements of TWPK which define the conceptualizations and practices system of each ST. This TAS is built on the IBST 6 dimensions model.

2.3. Expected findings

Two results are expected. Firstly, committed science teachers [CST] reach the upper levels of IBST 6 dimensions model. Secondly, CSTs who collaborate through professional networks and attend to specific CPD program about IBST reach more up levels than OSTs which can apply only on their own experience.

3. Results: teacher collaboration lead to learning focused teaching approaches

3.1. Proficient teachers involved within teacher collaboration through CPD

For all the dimensions of the model, the 8 CSTs reach at least level 2 of the continuum. All CSTs [8/8] reach levels 3 or 4 for half of the 6 dimensions and most of CSTs [5/8] for a least 4 dimensions. The lower mean [2.38/4] occurs for dimension 2 (nature of the problem). The higher mean [3.50/4] occurs for dimensions 4 (pupils diversity) and 5 (argumentation). Thus they are quite learner-centred.

3.1. Ordinary teachers applying only on their experience

All OSTs [4/4] are ranking at level 1 for at least 1 dimension of the model, mostly for dimension 1 (origin of questioning). Half OSTs [2/4] reach levels 3, which are learner centred, for half of the 6 dimensions. The other one [2/4] reach this level for 2 dimensions which are either dimension 4 (diversity), 5 (argumentation), or 6 (explanation). The lower means occurs for dimension 1 (origin of questioning) [1.50/4] and dimension 2 (nature of the problem) [1.75/4]. The higher means are achieved by dimension 4 (pupils diversity) [3.25/4] and dimension 3 (pupils responsibility) [3.00/4]. Thus they are globally teacher-centred.

3.2. Mastering learned-centred approaches and practices through IBST development

The mean of CSTs group is up than 2 for all the 6 dimensions contrarily of OSTs' which reach this threshold for only 3 dimensions. Thus results confirm what was expected: CPD based on teacher collaboration could contribute to improve the mastering of IBST complexity. Nevertheless OSTs are learner-centred for some crucial IBST dimensions: enhancing pupils' responsibility, considering positively their diversity, and promoting argumentation within inquiry. Thus, IBST by itself could promote more autonomous learning.

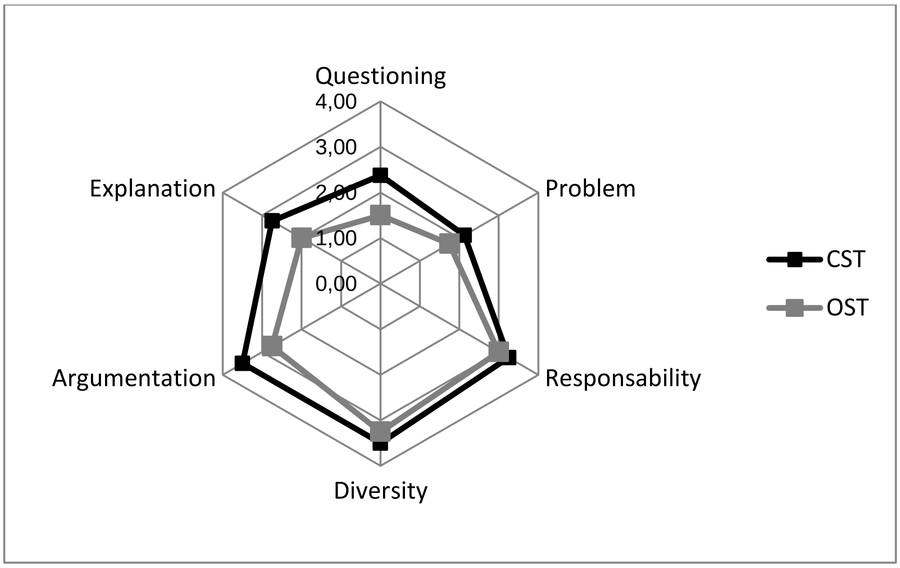

Figure 1: Locating teachers' strategies on IBST 6 dimension model

The graph which synthetized these results (see Figure 1) could make teachers, teacher educators or inspectors able to locate their own activity or an observed lesson. It could be an instrument used by actors to self-assess their IBST approaches and practices and to improve them, following specific directions and goals according to their own situation, needs and wills. The fact that teachers don't need to act at each upper level of each dimension could support their confidence in developing IBST. This was a goal of this paper.

3.2.1. Proficient science teachers' activity system

Within this paper length, it is impossible to describe the TAS of each ST. Thus this paper focuses of the activity system of CSTs' group with respect of the fourth dimension (diversity) of the IBST model. This could promote this aspect of IBST towards new and ordinary teachers.

Here is the main teaching work process knowledge [TWPK] for the 4 levels of this dimension.

3.2.1.a. Level 1: Coping with some pupils' behaviour in order to involve them within inquiry

All the CSTs act at least at this first level [8/8]. Their goals range from 2 to 6 (mean=4). These 4 goals are [within bracket the number of CSTs who aim this goal]:

- To support a pupil who encounters difficulties and to help him or her to enter within the inquiry process [7].
- To choose the right class-room with which developing IBST session [6].
- To gain pupils' attention and to support them to enter within the inquiry process [5].
- To adapt IBST lesson to the global class-room level [2].

The TWPK which corresponds to the goal which is more shared is (see Table 1):

Goal	To support a pupil who encounters difficulties and to help him or her to enter within the inquiry process
Clue	Some pupils are bogged down
Actions	I restore their confidence I support them really
Reference knowledge	I think it is crucial to begin by restoring their confidence: during peer-work they will understand that they are allowed and capable to propose their own questions and solutions. After that, learning and teaching could run in easiest ways.

Table 1: Supporting low achievers

3.2.1.b. Level 2: Adapting the activity in order to preserve pupils' involvement

Half of CSTs acts at this second level [4/8]. They share two goals:

- To maintain the activity of pupils who have completed the task before the others [3].
- To give time to all pupils to complete the inquiry [2].

The TWPK which corresponds to the more shared goal is (see Table 2):

Goal	To maintain the activity of pupils who have completed the task before the others
Clue	Some pupils are very advanced and there is a gap with other teams.
Actions	I propose another activity which complements the first.
Reference knowledge	I ever endeavour to prepare complementary activities for the teams who will achieve the inquiry before the others.

Table 2: Proposing complementary activity for advanced teams

3.2.1.c. Level 3: Assessing the problem understanding within each pupils' team

All the CSTs act at this third level [8/8]. Their goals range from 1 to 3 (mean=2). Most frequent goals are:

- To create pupils' teams [4].
- To help the teams which encounter difficulties [3].
- To choose the team which need teacher' help [3].
- To identify the product of each pupils' team [3].

The TWPK which corresponds to the more shared goal is (see Table 3):

Goal	To create pupils' teams.
Clue	When I want to promote exchange and discussion amongst pupils
Actions	I let pupils create the teams with their preferred mates.
Reference knowledge	The class-room is noisier with this way to create teams but the inquiry runs well. When I create teams by myself, it doesn't work as good.

Table 3: Creating pupils' teams

3.2.1.d. Level 4: Adapting the situation to specific pupils' particularities.

Half of CSTs acts at this fourth level [4/8]. They have 1 or 2 goals:

- Letting low achiever pupils express their opinions [2].
- Adapting the situation to disabled pupils [2].

One of the common TWPK is (see Table 4):

Goal	Letting low achiever pupils express their opinions
Clue	When a low achiever pupil is trying to express his or her opinion
Actions	I give time to finish his or her explanation
Reference knowledge	This kid is boring when other pupils are speaking, and the others are boring when this kid is speaking… But during IBST it's good to make an effort for this kid could express opinions.

Table 4: Letting low achiever pupils express their opinions

4. Conclusion

The IBST 6 dimensions model drawn from S-TEAM products and deliverables appears as a relevant mean to understand and assess science teachers' conceptualizations and practices when they carry out an inquiry-based lesson. The study had compared 8 teachers involved within specific CPD program with 4 ordinary teachers. It shows that teachers involved within CPD programs which promote teacher collaboration through exchange and controversy amongst attenders could achieve the highest levels of the IBST 6 dimensions model, which correspond to learning-focused approaches and practices.

Nevertheless, the fact that the sixth dimension of the model appears always amongst the weakest ask a crucial question: if teachers remain reluctant to make explicit the goals they want that pupils achieve through inquiry, we could think that most of these pupils cannot benefit of the inquiry to master more scientific knowledge. Here is a crucial challenge for improving IBST.

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