This paper considers the question of measurement of learners’ changes with respect to science teachers’ teaching approaches and practices. This question addresses the first of three objectives of the S-TEAM Project which is: To improve motivation, learning and pupil attitudes in European science education, resulting in increased scientific literacy and recruitment to science-based careers.

Within the S-TEAM project, the objectives of WP4 are:

- To use existing empirical research on teachers’ collective work as a basis for the systematic deployment of teacher collaboration in support of innovative methods in science teaching.
- To use teacher collaboration as a mean of promoting equity and working with diversity in science classroom.

The first goal consists in supporting change of teachers’ conceptions towards a more constructive consideration of difficulties at school. This change could occur through teachers’ participation in collective work which tackles explicitly the questions of learners’ activities in classroom and the management of learners’ diversity (Grangeat & Gray, 2007). In other words, the question is whether teachers can go from selective conceptions – which are content-centred and make them inclined to steer learners who encounter difficulties at school towards relegation (often vocational) courses and to consider major difficulties at school as unmanageable (Postareff & Lindblom-Ylänne, 2008) – towards equitable conceptions – which are learning-centered and influence them to design relevant resources for learners and to consider major difficulties at school as a challenge which can be overcome (Boaler, 2008). The second goal aims to spur pupils’ change about science achievement and intrinsic motivation, self-esteem and metacognition. Thus, despite the fact that the main part of the WP4 tasks is about enhancing teacher collaboration and collective work, it could be a nonsense if the project avoids to address the question of science learning outcomes. These outcomes consist in acquiring science knowledge, mastering scientific competencies, accessing science literacy, and enhancing motivation and metacognition about science. This paper focuses on this former type of outcomes.

It is quite clear that the nature of a support action such as S-TEAM means that measurement and verification of the objectives requires careful consideration. Thus, this paper focuses on the mean to assess learner's metacognition changes.

**Theoretical context**

Metacognition had been tackled by a lot of research since the papers published by Brown (1977) and Flavell (1976) which mark the beginning of the studies about ‘knowledge and cognition about cognitive phenomena’ (Flavell, 1979, p. 906). Nevertheless, the findings of these research remain unclear and require further studies. In order to design these studies, I will organize this section in three parts: firstly, an overview of the recent literature will precise the concept of metacognition and its linkage with motivation; secondly, some of the different tools used for assess metacognition will be discussed; thirdly, main indicators will be elicited.

**Metacognition, an overview**

The concept of metacognition gather two linked processes: the knowledge that a person built about cognition, and the regulation which this person act during cognition. The latter consists usually of three types of knowledge about individuals, tasks, and strategies. I will precise them along the next sections.

**Meta-knowledge about individuals**

Meta-knowledge about individuals gather beliefs and knowledge which are elaborated by a person about the ways human beings cope both with external information from their environment, and cognitive phenomena which could seldom be observed. Thus, these meta-knowledge address the spirit theory built by each person, and specifically each learner. They are connected with some learners’ important questions: how this curse could be understood? Is this abstract could be really memorized? Why some of my classmates seems to retain all this stuff so easily? Is my teacher a learner? Thus, these meta-knowledge play a central role for the access to a relevant attitude about learning. Consequently, they underline a lot of current research which frequently concern disabled
learners (Flavell, 2004; Peterson, Wellman, & Liu, 2005). These studies are quite closed to the research about motivation and self-esteem for they endeavor to understand the way learners build their own self-concept and the comparison they do between their own performance and their classmates (Marsh, Trautwein, Lüdtke, & Köller, 2008).

**Meta-knowledge about tasks**

Meta-knowledge about tasks consider the goals which need to be accomplished and the specificity of the information which had to be understood. These meta-knowledge refer to the understanding of what one is supposed to do, to the copying with the material with what one might to act, and to the management of the resources on which one could apply. Thus, these meta-knowledge play a central role for the learning achievement. They are also connected with some learners' important questions: what does the teacher really want? What kind of tools could be necessary to accomplish the task? If I face some trouble, how could I find some support? Nevertheless, they don't trigger a lot of studies. Actually, these questions are mostly connected to formative assessment and, above all, to the way students understand teachers' comments and prompts. The findings remain quite weak for the metacognitive phenomena require large time scales which are seldom used by most of the research [Berthold].

**Meta-knowledge about strategies**

Meta-knowledge about strategies consider the means to be used to accomplished the learning goals and, over all, the comparison between their respective efficiency. These meta-knowledge allow learners to steer their cognitive processes and performances trough an autonomous way. Thus, they could be ranked as the most important meta-knowledge. In the case of school learning, and over all within scientific domains, these strategies could often be make explicit; thus, learners and teachers could quite easily exchange about these strategies and the respective meta-knowledge. Such meta-strategic knowledge enable the learners to cope with crucial questions: what I know about the way to begin the task? What strategies could be useful? What means are available to assess the goals achievement? Studies lead to think that teaching explicitly meta-strategic knowledge could change learners' attitude toward science under two conditions: first, the learners need to encounter real scientific experiences —for instance, trough inquiry based learning; secondly, the teachers and the learners need to exchange and contract about the choice of the strategies required to accomplish the learning goals (Zohar & David, 2008).

**Regulation of learning**

The second process included within the concept of metacognition addresses the question of learning regulation. Regulation consists in three interconnected phases: planning, monitoring and adapting the learning activities in order to accomplished the required learning goals. Metacognitive regulation represents an on going phenomenon which produces a decision for a specific action about learning processes; consequently, one could think that it both generate and actualize meta-knowledge.

Metacognitive regulation is a multiform phenomenon which could be arranged on a continuum between implicit and explicit ways to steer the learning activities. Most of regulations are implicit and difficultly available for researchers. On the other hand, within specific situations, particularly within the school domain, they could be made explicit by the learners who explain and justify: how they begin the task, the plan they are designing, the way they are checking their own on-going learning process, why they change their first plan, and eventually, how they assess their performance. Thus, this former way is particularly interesting for researchers and most studies apply on this externalization of cognitive processes.

Metacognitive regulation occurs mainly in three phases of the learning activities. Firstly, during the first moments, when learners try to anticipate what they will do. Secondly, during the proper activities, when learners conduct their strategies, for instance by focusing on one specific point, or by postponing a difficult question, or by looking for resources. Thirdly, during the last time of the activities, when learners endeavor to assess their achievement. Some pedagogical approaches emphasize this former type of regulation, by postponing and institutionalizing this phase throughout specific teaching material (i.e. questionnaires) but no research findings showed the benefits of these kind of reflection, particularly within the secondary schools and for scientific matters.

The studies about metacognitive regulation lead to include or to connect the studies about motivation. Actually, metacognition appears as a high work load cognitive process and many students
The role of metacognition

could avoid it. Thus, meta-knowledge—even meta-strategic knowledge—is not enough to promote student achievement: motivation to use these strategies and to regulate cognition is also required (Pintrich & De Groot, 1990). Thus, motivation for a better school learning attainment play a key role. The self-regulated learning (SRL) perspective aims to take an inclusive perspective on student learning by including cognitive, motivation, and affective factors, as well as social contextual factors (Pintrich, 2004). This perspective products findings which show that high metacognitive level and high achievement level at school are correlated (O’Neil & R. S. Brown, 1998). Nevertheless researchers claim for further models that represent how motivation, metacognition and self-regulation interact and are related to the tasks and situations students confront (Kuyper H., van der Werf M.P.C., & Lubbers M.J., 2000).

Metacognition and motivation support, a goal for science teaching studies

To sum up, I could say that each of these three above types of meta-knowledge represents a research object. Nevertheless, in the S-TEAM project case, the third type —meta-knowledge about strategies— could appear as an decisive mean in order to improve pupils’ science learning achievements for the knowledge about strategies play a key role in inquiry based learning. Thus, the project partners might to pay attention to the teaching approaches which join, both inquiry based learning and metacognition supporting. Nevertheless, meta-knowledge is quite useless if it is not enacted through the learning regulation. Furthermore, learning regulation required motivation. Thus, the project partner might to pay attention to teaching practices which sustain both motivation and metacognitive regulation. But what indicators could be used?

Indicators

Most of studies focuses on students' learning and seldom on teachers' practices. Nevertheless, indicators about students could provide indicators about teaching. For instance, from the self-regulated learning indicators designed by Pintrich (2004), accurate practices could be produced. This model addresses four regulation areas (cognition, motivation, behavior, and context) through four phases (anticipation, monitoring, control, reaction).

From the few research which address teacher practices, two main findings result, and they appear as crucial for inquiry based learning success:

- Explicit teaching of meta-knowledge—specifically meta-strategic knowledge—is an effective instructional means for supporting the progress of students, particularly students with low academic achievements. This result occurs under the condition that explicit teaching of meta-knowledge aims to trigger learners to conduct active thinking and to foster deep understanding; thus explicit teaching does not mean “transmission of knowledge” or rote learning (Pintrich, 2002; Zohar & David, 2008).

- Collaborative exchange between peers of comparable expertise fosters the processes of metacognitive monitoring and regulation. Teachers have crucial role to play in organizing and orchestrating fruitful collaboration (Kramarski, Mevarech, & Arami, 2002; Goos, Galbraith, & Renshaw, 2002).

Within the below table, I precise indicators drawn on Pintrich’s model which could apply both for learning and teaching. Furthermore, I provide some examples of practices which results from findings of the few research above quoted.

Conclusion

Findings are unclear according to figure out whether meta-knowledge is required for effective regulation or regulation provide meta-knowledge through learning experiences. Nevertheless, some main results of this overview and could underlie further studies or support action.

- Metacognition teaching could deal with general skills about problem solving, but most of the research which show positive results deals with specific tasks.

- Metacognition is an individual process whom learners are not always aware, but making it explicit to the learners seems to be effective for the low achievers.

- Metacognition gather a multiform processes, but emphasizing the anticipation or on going aspects of them seems to secure the success.

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In S-TEAM project's case, we could discuss in what ways learners achievements and motivation enhance when teachers implement both inquiry based learning methods and self regulated learning supports.

<table>
<thead>
<tr>
<th>Metacognitive regulation phases</th>
<th>Cognition</th>
<th>Motivation</th>
<th>Behaviour</th>
<th>Context</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td>Planning and goal setting</td>
<td>Activation of perceptions, knowledge of the task and context, Self in relation to the task.</td>
<td>Prior content knowledge activation. Teacher organizes an exchange or uses a questionnaire about previous contents which will be accurate for the next inquiry.</td>
<td>Perceptions of task difficulty.</td>
</tr>
<tr>
<td>Monitoring</td>
<td>Metacognitive awareness of aspects of the self and task or context.</td>
<td>Metacognitive awareness. Teachers makes references to meta-knowledge pertaining to the current inquiry.</td>
<td>Awareness and monitoring of motivation and affect. Teacher responds to students who made mistakes by making it clear that their answers are wrong.</td>
<td>Monitoring of effort, time use, need for help.</td>
</tr>
<tr>
<td>Control</td>
<td>Efforts to control and regulate aspects of the self or task and context.</td>
<td>Selection and adaptation of cognitive strategies for learning.</td>
<td>Selection and adaptation of strategies for managing, motivation, and affect.</td>
<td>Help-seeking behaviour. Teacher organizes collaborative conversations between peers of comparable expertise.</td>
</tr>
<tr>
<td>Reaction</td>
<td>Reactions and reflections on the self and the task or context.</td>
<td>Cognitive judgements.</td>
<td>Affective reactions. Teacher gives students feedback, encouraged them to keep trying (e.g., Please check your answer carefully), and gave them emotional support.</td>
<td>Evaluation of task. Teachers ask students to reflect on their understanding and feelings during the inquiry process</td>
</tr>
</tbody>
</table>

References


